PROCEEDINGS FOR THE RIBES RISK ASSESSMENT WORKSHOP

17-18 AUGUST 1992
CORVALLIS, OREGON
USA

USDA-ARS NCGR
USDA-APHIS

INTRODUCTION

In April 1991, we at the USDA-ARS National Clonal Germplasm Repository (NCGR) in Corvallis, Oregon, observed unusual foliar damage to gooseberries growing in our field collection. Upon further investigation Repository staff, Joseph Postman and Bill Doerner, observed a small white eriophyid mite feeding on the young leaves. During that same time a similar yellowing leaf damage caused by a mite was observed on gooseberries in Booneville, California by Jim Xerogenes.

Animal and Plant Health Inspection Officers and State and County Inspectors visited both sites and collected specimens. The specimens were sent to Dr. Jim Amrine, Acarologist at West Virginia State University. The mite specimens from both Oregon and California were similar. Judging from published information at the time, the mites keyed out to be *Cecidophyopsis ribis* (Westw.), the black currant gall mite, known to be a vector of black currant reversion agent. USDA-APHIS immediately placed both collection locations under quarantine. *Ribes* plant material was not to leave either location.

Several pieces of data did not match.

1. No large galls were observed in dormant plants at either location.
2. These mites were infesting gooseberries, not black currants, although black currants were nearby.
3. Several microscopic details of mite morphology did not match written descriptions of *C. ribis* written descriptions.

Because of these incongruities USDA-APHIS sent Dr. Amrine to England and Scotland in August 1992 to work with scientists at East Malling and the Scottish Crop Research Institute and study samples of the eriophyids. Dr. Amrine determined that this new foliar mite had not yet been officially named and that several species or races of eriophyid mites had been observed to infest *Ribes* in the United Kingdom.

In the mean time we at the Repository chose to remove and burn our field collection. While we were relatively certain that we did not have the black currant gall mite, we felt that the mite we had was possibly exotic, and we did not wish to introduce this pest. While miticides such as endosulfan could be sprayed, we felt that this type of treatment would not eradicate the mite considering the large amount of foliage in our field collection. Members on our Small Fruit Crop Advisory Committee and Technical Committees suggested that removing and burning the plants would be best. We could then repropagate from clean material maintained in our screenhouse collection.

Both the Booneville, California and Corvallis, Oregon collections received a large shipment of gooseberries from Kent, England in 1989. These cuttings were brought in through Post-Entry Import Permits at both locations. We suspect that the foliar mites entered on this post-entry material.

Plant inspectors in California and Oregon did not find infestations of this mite in wild native gooseberries. APHIS inspectors also examined native gooseberry populations in Texas where an infested Repository field plant, *R. curvatum,* was native, but did not observe the mite there either. California and Oregon inspectors found this mite in other cultivated gooseberry collections of private homeowners and nurserymen. Burning the Repository field collection in 1991 proved effective. No mites were observed in any of the *Ribes* at the Repository in 1992.

We at the Repository were aware of the significance of reversion disease, and the effects of the black currant gall mite in European *Ribes*. These pests are not present in North America. We felt that by assembling a diverse interdisciplinary team of plant pathologists, acarologists, entomologists, horticulturists, and those involved with quarantine regulation and plant inspection, we could bring the problems involved with *Ribes*, eriophyid mites and reversion better into focus and determine practical recommendations to avoid importation of these exotic pests.

This situation caused us to realize that mites and *Ribes* warrant a closer look. Quarantine inspectors need to know what symptoms to look for to indicate the presence of mites. Those requesting Ribes need to become aware of difficulties in importing *Ribes*: Specifically, the significance of exotic diseases. Those writing quarantine regulations need to note potential agents which could be involved to accurately assess the risk of *Ribes* importation. To this end we organized a meeting August 17-18, 1992, in Corvallis, Oregon.
Our goals were to:

- Increase researchers' and growers' awareness of reversion and eriophyid mites on *Ribes*.
- Instruct plant inspectors concerning symptoms of reversion and the several forms of eriophyid mites affecting *Ribes*.
- Develop practical recommendations for allowing *Ribes* importation into North America with minimal risk from exotic pests.

In risk assessment one of the first steps involves defining the diseases and pests associated with the crop of interest. Dr. A. Teifion Jones, Plant Pathologist from Scotland described and itemized the diseases of concern. Dr. Jim Amrine, Acarologist from West Virginia enumerated and described the mites involved. Dr. Joe Foster, from the National Plant Germplasm Quarantine Center, Beltsville provided a historical view of *Ribes* U.S. importation regulations. Dr. Garry Wood provided insight from New Zealand, where the importation of *Ribes* has previously brought diseases and pests along with the crop. Horticulturists, Dr. Adam Dale and Dr. Rex Brennan, explained the important uses of these crops and their breeding and developmental potential including resistance to the pest and diseases.

In the laboratory, the group observed the foliar mite that had been misidentified as the black currant gall mite on fresh plant material from a Salem, Oregon gooseberry field. The participants were quite excited to see the mite and it's habits. These habits were quite different from those of the black currant gall mite.

Posters were displayed describing the ultrastructure of the black currant gall mite by Ian Roberts and Dr. A. Teifion Jones, the eriophyid mites at the Repository collection by Bill Doerner and Joseph Postman, and *Ribes* taxonomy by Wes Messinger et al.

We acknowledge and appreciate the support of USDA-APHIS and Dr. Arnie Tschanz, Head of Risk Assessment, USDA-APHIS, Hyattsville, Maryland, in the organization of these meetings. We hope that the following statements concerning problems associated in the risk assessment of *Ribes* importation will prove helpful in excluding exotic pests and yet allowing entry of novel germplasm.

Kim E. Hummer
Convener and Editor
USDA-ARS NCGR
Corvallis, Oregon
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LIST OF PARTICIPANTS

Dr. Jim Amrine, Acarologist, University of West Virginia, P.O. Box 6108, Morgantown, West Virginia 26506-6108, USA.

Dr. Rex Brennan, Plant Breeder, Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland.

Dr. Richard Converse, Plant Pathologist, Retired, USDA-ARS, Horticultural Crops Research Lab, 3420 NW Orchard Street, Corvallis, Oregon 97330, USA.

Dr. Adam Dale, Horticulturist, Horticulture Research Institute of Ontario, Box 587, Simcoe, Ontario N3Y 4N5, Canada

Mr. Bill Doerner, Agriculture Science Research Technician (Insects), USDA-ARS, National Clonal Germplasm Repository, 33447 Peoria Road, Corvallis, OR. 97333-2521, USA.

Dr. Joe Foster, Plant Pathologist, USDA-ARS, National Plant Germplasm Quarantine Center,, Building 580, BARC-E, Beltsville, Maryland 20705, USA.

Dr. Kim E. Hummer, Horticulturist, USDA-ARS, National Clonal Germplasm Repository, 33447 Peoria Road, Corvallis, OR 97333-2521, USA.

Dr. A. T. Jones, Plant Pathologist, Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland.

Dr. Jerry Krantz, Acarologist, Department of Entomology, Oregon State University, Corvallis, Oregon 97331, USA.

Mr. Wes Messinger, Graduate Research Assistant, Department of Botany, Oregon State University, Corvallis, Oregon 97331, USA.

Mr. Don Meyers, Grower, 3795 Gibson Road, Salem, Oregon 97304, USA.

Mr. Joseph Postman, Plant Pathologist, USDA-ARS, National Clonal Germplasm Repository, 33447 Peoria Rd. Corvallis, Oregon 97333-2521, USA.

Dr. Viktor Trajkovski, Horticulturist, Swedish Univ. of Agriculture Science, Division of Fruit Breeding, Fjalkestadsvagen 123-1, Kristianstad, Sweden S-291 94.

Dr. Garry Wood, Plant Pathologist, The Horticulture and Food Research Institute of New Zealand, Private Bag 92169, Auckland, New Zealand.

RIBES RISK ASSESSMENT WORKSHOP
SCHEDULE
OREGON STATE UNIVERSITY
AGRICULTURAL SCIENCES BUILDING, ROOM 4000

MONDAY, AUGUST 17, 1992

8:00-8:30AM	Welcome & Introduction	Dr. Kim Hummer USDA-ARS Corvallis, OR
8:30-9:30AM	Defining the Problem: Reversion, Mites in European *Ribes*	Dr. A.T. Jones SCRI Dundee, Scotland
9:30-10:30PM	Breeding Resistance in Black Currants to Reversion and Mites	Dr. Viktor Trajkovski Swedish University Balsgaard Sweden
10:30-11:00PM	BREAK	
11:00-12:00PM	Eriophyid Mites in *Ribes* Types, Races	Dr. Jim Amrine West Virginia State Univ.
12:00-1:00	LUNCH at Nendels	
1:00-2:00PM	U.S. *Ribes* Importation Regulations	Dr. Joe Foster USDA-APHIS Beltsville, MD
2:00-3:00PM	*Ribes* Research in Ontario,Canada	Dr. Adam Dale
3:00-4:00	BREAK	
4:00-6:30PM	Tour of *Ribes* Grower Salem, Oregon	Don Meyers Orchards and Nurseries
7:00-9:00PM	DINNER By Reservation-Prepaid	Airlie Vineyards Airlie, Oregon

TUESDAY, AUGUST 18, 1992

8:00-9:00AM	*Ribes* Perspective from New Zealand	Garry Wood
9:00-10:00AM	*Ribes* Breeding in the United Kingdom	Rex Brennan
10:00-10:30AM	BREAK	
10:30-11:30AM	Panel Discussion - Notes on Present Research Symptoms - What to look for; Erroneous reports; Difficulty in interpreting symptoms.	Drs. Jones, Wood, Trajkovski, Amrine, Krantz, Foster, Dale Moderator: Dr. Richard Converse
11:30-Noon	Summary discussion - Prevention of Mite and Reversion movement - Preparation of recommendations concerning Risk Assessment of *Ribes* Importation.	Moderator: Dr. Kim Hummer
Noon-1:00PM	LUNCH at Applebees Big O	
1:00-2:30PM	Demonstration laboratory Display of Eriophyid mites under scopes. Poster presentation of life cycle of three species of mites Poster display of reversion infection. cycle	Dr. Jim Amrine Dr. Jerry Krantz Mr. Bill Doerner Mr. Joseph Postman Dr. A. T. Jones
2:30-4:30PM	Tour of USDA-ARS National Germplasm Repository, Corvallis, OR Greenhouses Screenhouses Field Collection	Afternoon Break at the Repository

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Defining Problems, Increasing Awareness

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CONTENTS

Dr. A. T. Jones has worked as Plant Pathologist at the Scottish Crop Research Institute (SCRI) since 1969. His primary focus was initially with *Rubus*, but for the past 3 years he has also been investigating *Ribes* reversion disease. He has been examining possible graft transmissibility of reversion from black currants to gooseberries and he has been searching for the disease vector using electron microscopy and molecular techniques. Thus far he has observed that European reversion disease is not associated with a virus or mycoplasma-like organism (MLO).

DEFINING THE PROBLEM: REVERSION DISEASE AND ERIOPHYID MITE VECTORS IN EUROPE

A. Teifion Jones, Scottish Crop Research Institute, Invergowrie, Dundee DD25DA, Scotland.

About 14 distinct virus or virus-like diseases of significance have been recognized in *Ribes* and all have been reported to occur in Europe or Eurasia; although one, tomato ringspot nepovirus, was presumably imported from N. America. These diseases, their causal agents and vectors (where known) are given in Table 1. Of these diseases, reversion is unquestionably the most important for black currant crops worldwide, both economically and epidemiologically; it also affects red currant. The disease was first described in The Netherlands in 1904 but undoubtedly occurred before this. It is now known to occur in *Ribes* worldwide, with the exception of the Americas.

Table 1. Important virus and virus-like diseases of *Ribes*

Disease*	Causal Agent	Vector
Reversion	Not known	Gall mite
Interveinal white mosaic	Alfalfa mosaic virus	Aphid
Vein banding	Possible badnavirus	Aphid
Mottle	Cucumber mosaic virus	Aphid
Wildfire	Not known	Aphid
Leaf pattern	Tobacco rattle virus	Nematode
Green/yellow mottle	Arabis mosaic virus	Nematode
Mosaic	Tomato ringspot virus	Nematode
Spoon leaf	Raspberry ringspot virus	Nematode
(usually latent)	Strawberry latent ringspot virus	Nematode
(usually latent)	Tomato black ring virus	Nematode
Yellows	Not known	Not known
Infectious variegation	Not known	Not known
Full blossom	Mycoplasma-like organism	Leafhopper

*Disease symptoms are not evident in all *Ribes* species and cultivars

Reversion disease symptoms

The disease name reflects the change in plant habit, mostly in the leaves, that is suggestive of a "reversion" to a primitive ancestral type. In leaves of most black currant cultivars affected with reversion, this is usually characterized by a decrease in marginal serrations and a less clearly defined sinus at the petiole. However, these symptoms are sometimes difficult to distinguish from those induced by other causes, and diagnosis in some of the more recently produced cultivars derived from interspecific crosses is made difficult because the natural leaf morphology is not always typical of black currant. Symptom expression is also affected by the erratic distribution of the disease agent within the plant. In some cultivars and under some ill-defined conditions, leaves may develop a chlorotic line-pattern or oak-leaf pattern. It should be noted that cucumber mosaic cucumovirus, alfalfa mosaic virus, and some nepoviruses may induce similar symptoms. However, these viruses are readily distinguished from the agent of reversion by being transmitted by mechanical inoculation of sap extracts in 2% nicotine alkaloid to herbaceous test plants, such as *Chenopodium quinoa* and *Nicotiana clevelandii*, whereas the agent of reversion is not. For diagnosis, the most reliable symptoms occur in flower buds as they open in early spring. The precise symptom depends on the strain of the reversion disease; the common European strain (E) causes a marked decrease in the density of hairs on the flower buds, which is most noticeable just as the buds begin to open. A more severe form of the disease (R), found in Finland and countries of the former Soviet Union, in addition induces division of the sepals to form ten instead of five, and increases their pigmentation. Affected flowers are generally sterile. Leaf and flower symptoms in red currant are usually less marked than those in black currant (Adams and Thresh 1987).

Transmission

In nature, the reversion agent is transmitted between plants by the black currant gall mite, *Cecidophyopsis ribis (Westw.)*, which is itself a serious pest of black currant, inducing galling of buds, a symptom unrelated to reversion disease. Although other eriophyid mite species such as a foliar mite (Easterbrook, 1980) and *C. selachodon* (VanEynd.) have been identified on *Ribes*, it is not known if these mites can act as vectors of reversion. The reversion agent is not transmitted through seed. Experimentally, the agent is also transmitted by grafting but not by mechanical inoculation of sap extracts.

Properties of the Agent

Despite research over many years, the agent of reversion remains unknown. Earlier claims that it was a mycoplasma-like organism (Protsenko and Surgucheva, 1972) or a potyvirus (Jacob, 1976) have not been substantiated by other workers. However, it is generally believed that the agent is probably virus-like.

Epidemiology of the Disease

Gall mite vectors disperse from plants as infested buds open in early spring to early summer. The mites are spread by wind, although a few may also be carried by birds or insects that visit infested plants. Following arrival on new plants they move to colonize the young buds. The inoculum level from infested plants can be enormous. A single galled bud may contain up to 30,000 mites and an infested bush often contains over 100 galls. Furthermore, the altered physiology of reverted plants apparently makes them more suitable for mite colonization and production. Although the inoculum can be very large, the number of mites reaching a healthy bush during dispersal is very much greater than the number that survive and cause galls, and the number of galled bushes exceeds the number of bushes that develop reversion. This suggests that the main factor limiting the spread of reversion is the inability of dispersing mites to reach suitable feeding sites quickly enough for establishment and transmission of the reversion agent they may be carrying and/or the relative inefficiency of mites as vectors of the agent. However, the problems of accurate diagnosis of infection in field-grown plants and by the fact that, after infection, symptoms can take 2 or more years to develop in plants (Adams and Thresh 1987).

Control

In individual black currant plants or plant parts, gall mites can be eradicated from buds by immersing them in water at 46°C for 10-20 min. (Adams and Thresh 1987). Reverted plants can be freed from infection by heat-treatment of plants followed by graft inoculation of the apical tip to healthy plants (Campbell, 1965). Some *Ribes* species are heat sensitive and it is therefore best to heat-treat large, well-established plants at a lower than usual temperature (34°C) for a longer period (>20 days). Heat treatment at higher temperatures is possible if increased levels of CO_2 are used.

In the field, the only control measures currently available are to (a) plant healthy (certified) material, (b) rogue out as quickly as possible galled and/or reverted plants together with the adjacent neighboring plants which are symptomless, and (c) apply an effective systemic acaricide during the main mite dispersal period. Endosulfan is generally considered the only suitable and effective commercial product, but its use on black currant has been banned in some countries. Endosulfan is not listed for use on commercial *Ribes* fruit production in the United States.

For the future, the prospect of growing resistant cultivars has become a possibility following the identification in *Ribes* germplasm of resistance, possibly immunity, to the gall mite and to the reversion agent. Such resistant material is being used in breeding programs, and preliminary trials of advanced breeding lines containing such resistance genes, have been initiated by SCRI in Scotland and in Finland.

Detection

Because the agent of reversion has not been identified and characterized, no rapid test is

available for its detection in plants. As disease symptoms in different *Ribes* species and cultivars can vary greatly, the most reliable test is graft inoculation to black currant cultivars that are sensitive to infection such as 'Amos Black', 'Baldwin', or 'Ojebyn'. Because of the erratic distribution of the reversion agent in plants, several scions from different branches of the plant to be tested need to be used and the grafted indicator plants observed for symptoms for at least two flowering seasons. Although leaf symptoms are often produced in the indicator cultivars mentioned above, flower bud symptoms are considered the more reliable.

Priorities for Future Research

The international exchange of *Ribes* germplasm, research on the study of the mechanism and inheritance of resistance to the disease agent and on the epidemiology of the disease are all seriously hindered by the slow and laborious graft-indexing procedure required to detect and identify the disease agent in plants. Therefore, the first priority should be to identify and characterize this agent and devise rapid diagnostic tests for its detection. Secondly, the possible role as vectors of reversion, if any, of other mite species found on *Ribes* should be examined. Thirdly, the response of germplasm resistant to reversion should be tested to both the E and R strains of reversion, and of germplasm resistant to the gall mite and to the other mite species found on *Ribes*.

References

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Dr. Viktor Trajkovski is the State Horticulturist at the Department of Horticultural Plant Breeding in Balsgård, Sweden. He has been breeding *Ribes* since 1969. He has been the Director of the Institute and a stone fruits breeder since 1975.

Malcolm Anderson is a retired black currant breeder from the Scottish Crop Research Institute. He introduced the spring frost hardy "Ben" series between 1958 and 1987. 'Ben Lomond', has superseded the cultivar 'Baldwin' in the UK and is widely grown commercially in eastern Europe and elsewhere. 'Ben Alder' and 'Ben Tirran' combine spring frost hardiness, late flowering and late maturation to complement the harvesting season of 'Ben Lomond'. Seven other "Ben" cultivars have recently been named and released into commerce into New Zealand. Since his retirement in June 1987, Mr. Anderson has been acting as UK consultant to the Department of Horticulture Plant Breeding, Balsgård, Sweden.

BREEDING BLACK CURRANTS FOR RESISTANCE TO POWDERY MILDEW, GALL MITE AND REVERSION DISEASE

Victor Trajkovski & Malcolm Anderson, Swedish Univ. of Agriculture Sciences, Division of Fruit Breeding, Fjalkestadsvagen 123-1, Kristianstad, Sweden S-291 94.

Within the constrains of the major objectives of the Balsgård black currant breeding program, which are winter hardiness, spring frost hardiness and mildew resistance, breeding for resistance to reversion disease and its gall mite vector have high priority. Fortunately, a wealth of donor parents is at our disposal from the breeding programs in the former USSR, Lithuania, Poland, the UK and elsewhere. The policy at Balsgård is to make cooperative exchange agreements with our fruit breeding colleagues around the world, and to test whatever germplasm is available from their programs. Cultivars or selections best adapted to Scandinavian climatic conditions or with some outstanding attribute are used as donor parents. In the past, we have been glad to receive gall mite resistant black currant x gooseberry hybrids from East Malling (now IHR, East Malling), and non-galling and reversion-resistant cultivars from the former USSR.

Currently, black currant breeding material is being assessed at Balsgård in cooperation with the Scottish Crop Research Institute; the All Union Research Institute of Horticulture, Michurinsk, Russia; the Institute of Horticultural Plant Breeding, Orel, Russia and the Institute of Horticulture, Babtai, Lithuania.

Studies on Breeding Black Currants for Resistance to *Sphaerotheca mors-uvae* (Schw.) Berk

The susceptibility and resistance of several hundred of cultivars, species and hybrids were investigated during the period 1969-1974. The most common commercial cultivars proved fully susceptible. Only two varieties from Northern Sweden, namely Sunderbyn II and Matkakoski and the species *Ribes dikuscha (Fisch. ex Turcz)*, showed high resistance in greenhouse and field tests. Fourteen races of *Sphaerotheca mors-uvae* were identified. The mode of inheritance present in Sunderbyn II, Matkakoski and *Ribes dikuscha* was studied. The resistance of the Nordic varieties Sunderbyn II and Matkakoski seems to be controlled by a single dominant gene or by a block of closely linked genes. The resistance of *Ribes dikuscha*, however, seemed to

be governed by genes with complementary effect at two separate loci (Trajkovski and Pääsuke, 1976).

The stable resistance in black currants seems to be due to an interaction between two properties, the first being operative in newly developed shoot tips during a period when primary infection normally takes place. At this time resistant genotypes were characterized by accumulation of low amounts of ascorbic acid while the concentrations of ortho-dihydroxy-phenols were relatively high. In addition, the polyphenol oxidase and peroxidase activities were greater in shoots of resistant genotypes than in susceptible ones (Trajkovski, 1976).

From these results it may be concluded that the defense reaction involves biochemical actions between host tissue at this stage of development and the invading pathogens, particularly in oxidation reactions of chlorogenic acids to quinones and quinone-polymers. These defense reactions cause no visible signs of infection, and under the microscope only single necrotic cells can be observed.

About one week after primary infection the resistance is also governed by the rapid development and maturation of the epidermal cells, which results in a high order of protection against secondary sources of infection.

The combination of these two properties brings about a high order of protection against both primary and secondary sources of infection under glasshouse and field conditions, in that no macroscopic evidence of infection is to be found.

It remains an open question whether these two properties governing resistance can act separately or only in connection with each other, a problem that needs further investigation.

Phenolic patterns of several resistant and susceptible hybrids belonging to the *Ribes nigrum* group were compared (Trajkovski, 1972, 1974a and 1974b). The differences observed were primarily associated with the content and accumulation of phenolic acids during the growth season. The highly resistant variety Sunderbyn II accumulated large amounts of isochlorogenic and neochlorogenic acids, while the accumulation of chlorogenic acid is characteristic of the Russian varieties. On the other hand, varieties susceptible to mildew showed very low accumulation of these compounds.

Further study in cooperation with the Nordic Genebank showed that the wild growing populations of *Ribes nigrum* L. in Northern Sweden from which Sunderbyn II and Matkakoski are selected, possess genes that confer high resistance to a very wide spectrum of races of the fungus. The important finding from the viewpoint of plant breeding is that the resistance of Sunderbyn II and Matkakoski has remained effective for over 50 years. The first varieties from the breeding program mentioned above, Storklas (Sunderbyn II x (Consort x Kajaanin Musta), and Polar (Silvergieter's Black x Sunderbyn II) x Nikkala XI are now protected by Plant Breeders Rights.

The Selection and Breeding of Black Currants Resistant to Reversion Disease and its Gall Mite Vector [*Cecidophyopsis ribis* (Westw.)]

Black currant reversion disease, caused by a probable virus or a virus-like pathogen and transmitted by a bud-inhabiting gall mite vector [*Cecidophyopsis ribis* (Westw.)], is the most serious disease affecting black currants worldwide. The mite vector is difficult and expensive to control, even with several annual spray applications of endosulfan, and in parts of Eastern Europe reversion disease is out of control.

All Western European cultivars are susceptible both to infestation by the gall mite and to infection with reversion disease, which renders the flowers of an infected bush sterile. In addition, the virus induces certain morphological changes in the infected plant which predisposes it to further massive infestation by mites. Systemically reversion-infected bushes and branches are easily recognized in winter because they are overlaid with mite infested gall buds from top to bottom, including the terminal bud (Thresh, 1964, 1967).

Healthy plants in new plantations are infested at random by infective mites which are carried by air currents out through a plantation during the dispersal period from newly expanded galled buds, normally during May or June in Sweden. Such infected bushes act as foci for the rapid secondary spread of infected mites <u>within</u> a plantation, by far the most important means of shortening its viable economic life.

These interactions between the plant, the pathogen and its mite vector have important implications for the control of reversion disease and its mite vector by breeding resistant cultivars.

Sources of resistance to the gall mite vector

1. Sources within black currant species

By contrast with Western European cultivars, mite-infested buds of cultivars of the black currant species *Ribes nigrum* var. *sibiricum* W. Wolf., *R. ussuriense* Jancz., *R. pauciflorum* Turcz. and *R. petiolare* Doug. become necrotic instead of proliferating to form a gall. Mites are able to feed within the buds for long enough to transmit reversion disease to reversion-susceptible host plants, but they are unable to survive and reproduce (antibiosis). This reaction to mite infestation is controlled by a single dominant gene, P (Anderson, 1971).

Pavlova (1964, 1969) used as donor parents for gall mite resistance *Ribes nigrum* var. *sibiricum*, *R. ussuriense*, and accessions of *R. pauciflorum*, one of which is reputed to be immune (Pavlova, 1963). Ravkin (1978, 1980), found the cultivar Naryadnaya (Boskoop Giant x Altajsky Velikan) a donor of a high degree of resistance in breeding, and that the influence of the second parent was pronounced: 24-66% of resistant seedlings were selected in different progenies. Naryadnaya has been found to be resistant to bud galling in Scotland (Anderson,

1971), Poland (Gwozdecki, 1983) and Sweden (Larsson, 1984). However, experience in Scotland and the former USSR has shown that progenies derived from crosses between European *Ribes* var. *sibiricum* cultivars, notably Rus and Naryadnaya are partially self-sterile (Anderson, unpublished; Kuminov 1962; Keep, 1975).

In a conventional breeding program several generations of backcrossing may be necessary (35-40 years, as with black currant x gooseberry hybrids at East Malling) to transfer the genes controlling resistance to galling into a commercially acceptable cultivar. In Poland, however, a non-galling cultivar, Ceres (formerly hybrid 76/69 = S/26 *R. dikuscha* x Barchatnaya (Baldwin x *R. nigrum* var. *sibiricum*)), resulting from open pollination in 1969, has recently been introduced by Gwozdecki (1988).

At the Institute of Horticulture, Babtai, Lithuania, resistance to gall mite was shown by four black currant selections obtained by crossing Stakhanovka Altaya with Sovkhoznaya (Lutoshyavichyus, et al., 1987). In Novosibirsk, Potapenko (1985) selected the cultivars Agrolesovskaya, Berdchanka and Iskitimskaya which are reputed to have field resistance to *Cecidophyopsis ribis*. They are recommended as donors for this attribute along with the cultivars Durzhnaya and Altaiskaya Desertnaya.

Saumjan (1964) found the cultivars Blestjashchaya and Zhelannaya resistant both to infestation by the gall mite and infection by reversion disease. In European Russia Khokhoyakova (1966) found that *R.n.* var. *sibiricum* and cultivars of the small flowered black currant, *R. pauciflorum*, showed multiple resistance to reversion disease, *Cecidophyopsis ribis*, fungi and aphids.

Volodina et al., (1988) found high resistance in Binar (Pamyati Pavlovoi), and the *R. pauciflorum* cultivars Pilot Alexander A. Mamkin and Tusklolistnaya, a hybrid of Pamyat Michurina x Sveryanka (hybrid 17-1-7) and three other hybrids.

Ravkin (1987), after a lifetime devoted to fruit breeding, has described progress in black currant breeding in the former USSR, and Melekhina et al. (1968) in Latvia listed the sources of resistance to *Cecidophyopsis ribis* in *Ribes* species, together with their salient characteristics which are of interest in breeding. In Latvia over a four year period Grosa (1984) found combined resistance to gall mite, red spider mite and three common pathogens of black currant in the cultivars Polli Garkekarota (Polli Pikk-Kobar), Mechta, Paulinka, Pilot A. Mamkin, Primorsk Champion, Minskaya, Sopernik, Minai Schmyrev and three numbered hybrids.

2. Sources of gall mite resistance in other *Ribes* species

The gooseberry (*R. grossularia* L.) has been grown adjacent to galled black currant bushes for many decades and in several countries without becoming infested by gall mite (antixenosis) or infected by reversion disease, hence its use as a donor parent in breeding at East Malling, Kent and at the Institute of Horticultural Plant Breeding, Orel.

Fertile, gall mite resistant black currant x gooseberry hybrids were obtained at East Malling in

1953 by treating sterile F_1's with colchicine and backcrossing the allopolyploid to diploid black currant (Knight and Keep, 1957). The major dominant gene (or a small segment of a gooseberry chromosome behaving as a unit), designated Ce (Knight, et al., 1974) controlling this form of resistance is not associated with any morphological marker genes, and resistant plants in segregating progenies can be recognized only by their response to the gall mite. Progenies at East Malling were therefore routinely exposed to natural infestation by mites in a gall mite field infestation plot for a period of four years.

Mites were unable to infest the buds of resistant plants, but the occurrence of about one-fifth of mite resistant seedlings with reversion disease symptoms showed that infective mites can occasionally feed long enough to transmit the disease.

Bayanova (1984) at the Institute of Horticultural Plant Breeding, Orel found promising donors of resistance in black currant x gooseberry hybrids, and in hybrids of *R. nigrum* crossed with *R. cereum* Dougl., *R. glutinosum* Benth. and *R. janczewskii* A. Pojark.

Mechanisms of gall mite resistance

In Germany, Herr (1988, 1991) studied the mechanism of gall mite resistance in resistant and susceptible plants in the field and found both antixenosis and antibiosis in black currants, antixenosis in gooseberries and antibiosis in red currants.

Sources of Resistance to Reversion Disease

Fruit breeders at the Altai Horticultural Research Station were the first to use an accession of the Siberian Blue Currant, R. *dikusha* Fisch., as a source of reversion resistance (Pavlova, 1962). This led to the introduction of the reversion resistant (but gall mite susceptible) cultivars Primorsk Champion (*R. dikusha* x Lee's Prolific) and Golubka (Saunders x Primorsk Champion). Golubka has been widely used as a parent in breeding in former USSR to produce series of cultivars. It has also been used as a donor parent in the UK (Keep, 1975; Anderson and Taylor, 1985). One of Anderson's reversion resistant hybrids, SCRI F4/1/67 (Ben Alder x Golubka) is currently being tested in the UK and at Balsgård.

At East Malling Research Station the cultivars Golubka, Blestjashchaya and Severyanka were found to be resistant to reversion disease. They failed to develop symptoms after graft inoculation, and back tests were negative after three years, indicating that these cultivars are immune to reversion disease rather than tolerant (Knight, 1981,1985).

Other cultivars that have remained symptom-free at East Malling after graft-inoculation include Batyka Minay, Gelannaya, Byelorusskaya Sladkaya, Zolushka and Pilot Alexander Mamkin (Knight, 1985). In earlier tests, graft-inoculated plants of *R. grossularia, R. cereum* and *R. nigrum* x *R. cereum* remained symptom-free, and back grafts to *R. nigrum* indicator plants proved to be negative (Anon, 1966).

Nature or form of reversion resistance

The gene or genes conferring resistance to reversion disease in cultivars of *R. dikuscha, R. nigrum* var. *sibiricum* and *R. pauciflorum* have not been identified, and the form of resistance is still uncertain (Björling, 1966; Ponz and Brüning, 1986; Fraser, 1987, 1988). At East Malling, segregation ratios in four graft-inoculated progenies of Glubka suggest that this cultivar is probably heterozygous for a single dominant gene conferring a form of resistance to reversion disease (Knight, 1985).

R.L. Knight et al., (1974) selected gooseberry as a donor parent for combined gall mite and reversion resistance. Although neither workers at East Malling (Anon, 1966) nor Tiits (1970) was able to infect *R. grossularia* with reversion by graft inoculation, a *R. nigrum* x *R. grossularia* hybrid was infected in this way, suggesting that the gooseberry gene is recessive (Keep, 1975).

Selection and Breeding at Balsgård

All of the following species have been used as donor parents in Sweden, Latvia, Lithuania, the UK or the former USSR, and many of them or their hybrids have found their way to Balsgård as a result of cooperative agreements.

Sources of resistance to gall mite:

a) the gooseberry (*R. grossularia* L.), *R. divaricatum* Dougl;

b) black currant species or sub-species in the *Eucoreosma* Jancz. (*Botrycarpum* A. Rich.) sub-genus of *Ribes*, notably *R. nigrum sibiricum* W. Wolf; *R. ussuriense* Jancx., native to N. Korea; *R. pauciflorum* Turcz., native to Manchuria; *R. petiolare* Dougl., N. America, Siberia and Manchuria; *R. janczweskii* A. Pojark., Central Asia;

c) *R. cereum* Dougl. from Western N. America;

d) *R. glutinosum* Benth. native to California;

e) a hybrid of the relatively new, hardy, frost-resistant, self-fertile black currant species *R fontaneum* Boczkzar (Lihones and Pavlova, 1968, 1969; Stephanov, 1974) from the Far East is under observation.

f) two inter-specific hybrids of particular interest which are used in the breeding program at Balsgård are *R. nigrum* x *R. petiolare* (3691-N-2) and 2244N-1) bred by A. Ravkin, Bjurulovo, Moscow. The hybrid (3791-N-2) is notable for its productivity, long inflorescences with a pronounced 'handle', good fruit setting but poor flavor. This hybrid has good potential for developing a gall mite resistant cultivar specifically for PYO (pick-your-own) purposes

Sources of resistance to reversion disease

Accessions of three black currant species have been used in breeding as donors of resistance to reversion disease. These are *R dikuscha* Fisch., *R. nigrum sibiricum,* W. Wolf. and *R. pauciflorum* Turcz. Cultivars derived from these species are of particular and immediate interest because they hybridize readily with West European cultivars.

Outstanding among the reversion resistant cultivars and hybrids on trial at Balsgård is SCRI F4/1/67 (Ben Alder x Golubka). The breeder of this hybrid, M.M. Anderson, graft-inoculated it in 1984, and it has so far remained free of reversion disease symptoms at Balsgård. Several progenies of this hybrid fruited in 1992.

Among recent acquisitions for testing, three cultivars bred in the former USSR have so far remained free from galled buds and symptoms of reversion disease: Orlovija (an open-pollinated Brödtorp hybrid) Kosmiczeskaya (Stahanovka x Vistavotnaya) and Smugljanka (Pamjat Michurina x Golubka) x (Vistavotnaya x Narjadnaya). Although much less productive than the first two cultivars, Smugljanka is of interest because its parentage contains donor parents both for non-galling-Narjadnaya-and for resistance to reversion disease-Golubka. Since Narjadnaya is a notoriously poor parent in breeding (Ravkin 1987, Anderson, M.M., unpublished) Smugljanka is a possible replacement donor parent for Narjadnaya.

Balsgård selections made in 1992

Selection after screening for mildew resistance was carried out in five progenies of an East Malling fifth back cross black currant x gooseberry hybrid crossed with Storklas, Ben Alder, SCRI F4/167 (Ben Alder x Golubka) and two unnamed elite selections. Although productivity of the hybrids in an extremely dry season was generally poorer than the gall mite resistant parent, several selections were made for gall mite resistance screening.

In two progenies segregating for reversion disease resistance, selections in F4/1.67 x Polar (formerly *Ri74020-6*) were particularly outstanding. These selections will be graft-inoculated in 1993.

Conclusions: East Malling's experience with their black currant x gooseberry hybrids suggest that gene Ce prevents or delays infection with reversion disease (Knight 1981a). An apparent advantage of gene Ce over gene P is that a proportion of Ce-carrying plants do not become infected with reversion disease, even after four years exposure in a gall mite infestation plot (knight 1981). With gene P-carrying cultivars, bud meristem necrosis and the subsequent desiccation of the bud tissues prevents or severely limits secondary virus spread by infective mites within a plantation, but not the establishment of primary infections. The advantages of combining the form of resistance to the reversion pathogen present in Golubka with resistance to galling may therefore be of considerable value in reducing mite populations and delaying or preventing the appearance of new vector biotypes.

It remains to be seen how stable these forms of resistance remain after resistant cultivars become common in cultivation, and the mite and the pathogen are deprived of their normal hosts. In the meantime, 100 selections from the late Professor Fredrik Nillsson's *Ribes* species collections at Alnarp, selected by M.M. Anderson in August 1987, have been sent to the Scottish Crop Research Institute to be screened in a gall mite infestation plot for resistance to reversion disease and its mite vector.

New techniques are urgently required which would quickly and unequivocally distinguish between gall mite and reversion resistant and susceptible seedlings. Volodina et al. (1988) in Leningrad evolved a method of assessing gall mite resistance based on changes in the color of the cell sap in light. The cell sap of resistant cultivars showed no change in the green color of the chlorophyll after standing in the light for 1-3 days, whereas that of the susceptible ones changed to light or dark brown. The results obtained by visual assessment of the color change accorded with those of the field assessment. It is supposed that flavonoids in the resistant plants prevent oxidation of the chlorophyll in light and thereby increase resistance.

To reduce or eliminate the need for a 4-year period of field exposure in a gall mite infestation plot, Austin et al. (1983) in England developed a metabolic profiling technique (Anon, 1984) of leaf tissues which identified mite resistant black currant x gooseberry genotypes with a probability of about 70%. This technique has been improved at SCRI and has proved to be successful in 88% of the genotypes examined, giving good prospects for the use of this technique in preference to field assessment (Brennan et al. 1992).

An equally rapid and reliable technique is still required to distinguish between resistant, gene P-carrying and susceptible genotypes and reversion resistant and susceptible seedlings.

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Jim Amrine obtained his Ph.D. from Ohio State University working on black flies. He began an assignment at West Virginia State University in 1975, and is presently Professor of Entomology. He has been specifically studying eriophyid mites since 1984.

ERIOPHYID MITES ON RIBES[1]

James W. Amrine, Jr., West Virginia University, P.O. Box 6108, Morgantown, West Virginia 26506-6108.

In April 1991, a sample of eriophyid mites from gooseberry cultivars (*Ribes grossularia* L.), originally shipped from England to California, was submitted to me for identification by Dr. Ron Somerby, California Department of Agriculture, Sacramento, California through the USDA, Systematic Entomology Laboratory (SEL), Beltsville, Maryland. The plants in question were in postentry at Booneville, California. I made an initial search of the literature for mites on *Ribes spp.* especially regarding those on *R. grossularia, R. nigrum* L. and *R. rubrum* L. I found an illustration which matched this mite in the text by H.H. Keifer, 1975, "Injurious Eriophyid Mites" (in Jeppson, Keifer and Baker, eds., Mites Injurious to Economic Plants, University of California Press, p. 412, Fig. 109). Unfortunately, this drawing was mislabeled as *Cecidophyopsis ribis* (Westwood) which I did not realize until later. The mites in question were initially misidentified in April as *C. ribis*, based on the scientific literature at hand.

The descriptions in the text of the habit and plant injury caused by *C. ribis* did not match the descriptions of the habit of the mites submitted from on gooseberries from California. The gooseberry mites caused foliar injury, misshapen leaves, cavities at bases of veins on the undersurface of the leaf blade and small enations or blister-like tissue enlargements on the leaf. The text by Keifer did not indicate the host plant, location, or source for the mite illustrated in Fig. 109. I presumed that the mite was collected from gooseberries from one of the western States in the U.S.A., rather than from big bud galls of black currant, *R. nigrum*, the preferred host of *C. ribis*.

I made a note in my identification that I thought the mite was probably present in northern California and Washington, especially on gooseberries, based on reports from the literature. Subsequently, regulatory personnel submitted several samples from various cultivated gooseberries grown in California and Oregon and many were found infested with this same eriophyid mite. Dr. Kim Hummer and Mr. Bill Doerner, USDA, ARS, of the National Germplasm Repository at Corvallis, OR found considerable numbers of the mites on many gooseberry cultivars in their collections, both in the field and in greenhouses. However, the repository had gooseberries in post-entry quarantine from the same English shipment that was infested with mites in California. They also found the mite on cultivated *Ribes curvatum* Small in the repository collection. This gooseberry species is native to the south central United States. Mr. Jim Xerogeanes, County Agent for Mendocino Co., California, submitted a record of infestations of the mite from gooseberry cultivars at several locations in that state. These locations had each received gooseberries from the Booneville location. Jim also surveyed the following native *Ribes* in natural settings, but found no eriophyids: *Ribes quercetorum* Greene, *R. roezlii* Regel, *R. californicum* McClatchie, *R. menziesii* Pursh, *R. nevadense* Kellogg, and *R. sanguineum* Pursh.

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The absence of this mite from these native plants is a strong indication that the mite was probably imported on the gooseberry, *Ribes grossularia*, from England. The known infested plantings of cultivated gooseberries were destroyed in California and at the repository in 1991.

I noted in my reports that I needed samples of mites from the big bud galls of *R. nigrum* from England to be absolutely sure that the mite in question was *C. ribis*. No such samples were in collections in the Systematic Entomology Laboratory in Beltsville, MD, or in the collections of Agriculture Canada (per Dr. Evert Lindquist, Senior Acarologist).

In August 1991, the USDA-APHIS, supported my travel to the Scottish Crop Research Institute, Dundee, Scotland, to visit Stuart Gordon, Zoologist, and Dr. A. T. Jones, Virologist, who were working on currant reversion disease and *C. ribis*. By their generous assistance, I was able to make slides of the mites from newly developing big bud galls on *R. nigrum*, and to make several dried collections of infested black currants for future study. I then traveled to East Malling, Kent, England to visit Dr. Mike Easterbrook who generously spent his valuable time helping me collect samples from big bud galls of black currant and a few mites from buds of gooseberry. Easterbrook (1980) published a paper on a "non-gall-forming" eriophyid mite living in the buds on *Ribes* and was close to resolving the taxonomic problem of these mites. In his report, he stated plans to conduct future tests of the "foliar" mite as a vector of currant reversion disease. The mission of East Malling Research Station was changed to berries, vine and apples, and most of the *Ribes* collections and research materials were transferred to the Scottish Crop Research Institute at Dundee. As a result, the transmission experiments with the "foliar" *C. ribis* were not completed. Dr. Easterbrook also generously provided me with a sample of mites (*C. selachodon* Van Eynd.)causing big bud galls on red currant which he had received from Sweden.

Returning to WVU at Morgantown, I made slides, photomicrographs and measurements of all three mites: the *C. sp.* from gooseberry, *C. ribis* from black currant big bud galls, and *C. selachodon* from red currant big bud galls. In my opinion, all three are distinct and separate species. I conducted a literature search on the eriophyid mites on *Ribes* and found a total of 14 valid species developing on various *Ribes* species. The information on each of these mites, illustrations as well as a full citation of taxonomic references to these mites are available in the appendixes. One species, *Eriophyes grossulariae* Collinge 1907, seemed to me to be a candidate for the original description of the "foliar" mite on gooseberry and red and black currants. In September 1992, I obtained a copy of Collinge's paper (it had been misquoted in the literature of Eriophyids), and I am convinced that this is indeed a valid description of the foliar mite and the same mite that was illustrated by H. H. Keifer in Fig. 109, mentioned above. Collinge listed the type locality for *E. grossulariae* as "Eastham", England. He stated that the mites occur in buds of gooseberry, and that the bud scales were affected and buds became dried and shriveled rather than enlarged as caused by *C. ribis*. The mites collected by Easterbrook and myself from the buds of gooseberry at East Malling are the same mite illustrated by Keifer, and these were found under the bud scales. In contrast, *C. ribis* is found developing not under the bud scales but in the center of the bud, above and among the developing flower buds. I believe this foliar mite of gooseberry and currants should be named *Cecidophyopsis grossulariae* (Collinge) 1907. I also believe that the mite is native to England and Europe, and was brought to the Pacific northwest of the USA on cultivated gooseberries.

A summary of the biology of the three *Cecidophyopsis spp.* follows:

1. *Cecidophyopsis ribis* (Westwood) 1869. These mites, as single dispersing females enter larger buds on the lower part of stems during the early summer and begin reproducing within the central chambers of the buds. By mid-August, both sexes are present, and numbers have risen to as many as 20 to 100 mites in infested buds. Population growth continues in the buds in the fall until temperatures become too low (2-4° C) to allow development, and the mites enter a "resting" stage. As temperatures begin to rise in February and March, the population explodes, so that by late March, thousands of mites may be found within each enlarged bud gall. During April to June, the mites exit the buds, crawl over the foliage or disperse into the air, seeking new buds large enough to allow the females to gain entry to the central chamber and begin reproduction. Not all galled plants are infected with currant reversion disease, and not all mites transmit Currant Reversion. The mite, *C. ribis*, is the only proven vector of currant reversion disease. <u>NOTE</u>: This mite was reported from bud galls on *Ribes alpinum* L. by Roivainen (1951, p. 17,) in Finland; these mites should be collected from *R. alpinum* and carefully studied to determine whether the species is *C. ribis* or perhaps a separate species that is restricted to *R. alpinum*. They should also be tested as potential vectors of currant reversion disease to *R. alpinum, R. nigrum* and *R. rubrum*.

2. *Cecidophyopsis selachodon* (van Eyndhoven) 1967. The biology is probably nearly identical to that of *C. ribis*, except that development only occurs on red currant, *Ribes rubrum*. This mite is much rarer than *C. ribis*, and is apparently only found in Europe: the Netherlands, Germany, Poland, and Sweden. Massee (1928) reported on the "black currant gall mite" (*C. selachodon*?) on red currants, but I have not seen this paper and do not know if the plants were from Great Britain. Biological experiments by van de Vrie (1958) in The Netherlands show that the two mites cannot be exchanged between black and red currants; colonies fail to develop and where mites gain entry to buds of reciprocal plants, the tissue becomes necrotic. Apparently, reversion rarely occurs in red currants, and *C. selachodon* should be considered as the probable vector; but, *C. ribis* may be the vector and the agent may be transmitted within an attacked bud before the mites die. Further experiments in transmission of currant reversion disease, by both mite species and to reciprocal plants should be conducted. Preferably, the work should be conducted where both red and black currants, reversion in both plant species, and both mite species can be found. This species is very close morphologically to *C. ribis*; some investigators believe that they are one and the same species. However, the biological experiments by van de Vries support the separation of the species, and dependable characters need to be found to confidently separate them with the microscope.

3. *Cecidophyopsis grossulariae* (Collinge) 1907. Females of this mite exit normal sized buds of *Ribes grossularia, R. nigrum, R. rubrum,* and *R. curvatum* in early spring and begin oviposition and development on the leaf blades of new growth. Symptoms caused by the mites are mostly deep, hairy cavities at the base of the veins on the undersurface of the leaves, foliar deformation and discoloration, and in some species, the development of

enations on both leaf surfaces. By summer, many females have entered the buds, residing at the base of bud scales; they do not enter the inner chamber of the bud. Any new growth of leaves during the summer can be attacked, but apparently, mature leaf blades cannot support further development. In August and fall, the females aestivate under the bud scales and apparently no further development occurs. But this aspect of development needs additional study in light of the original description by Collinge. Dispersal probably occurs shortly after leaves mature, but experiments need to be conducted to prove this hypothesis. This mite should be tested for potential transmission of currant reversion disease. This species is easily distinguished from *C. ribis* and *C. selachodon* by details of the structure of the coxal-genital annuli.

In summary, I believe there are three species of *Cecidophyopsis* known to occur on *Ribes*, and a total of 14 species of eriophyids presently known to occur on these plants worldwide. In addition to the work suggested above, considerable taxonomic and biological work needs to be done on the eriophyids attacking *Ribes*, especially finding and redescribing some of the species very briefly described from plants in Europe. Competent, basic taxonomic and biological work must be conducted on these important phytophagous mites in order to prevent misunderstandings and expensive errors like that of 1991 from occurring in the future. With more than 150 species in the genus *Ribes*, and there will undoubtedly be several more new species of eriophyid mites found and described from these plants in the future.

Dr. A. T. Jones and coworkers at SCRI are conducting scanning and transmission electron microscopy of *C. ribis*, for both virological and taxonomic investigations. They mention plans to study the other *Cecidophyopsis* species, if they can obtain specimens. I plan to assist Dr. Jones and SCRI in these investigations and to redescribe the three *Cecidophyopsis* from currants and gooseberries.

I prepared further information and descriptions of the *Eriophyoideae* in *Ribes* for the appendix of these proceedings.

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Disclaimer: In this paper I have made references to the work of many researchers on Ribes, currant reversion disease, and eriophyid mites. Any errors or incorrect conclusions are solely mine and should not be reflected on the persons mentioned.

Joe Foster obtained his Ph.D. from Cornell University in Plant Pathology and worked as a Post-doctoral investigator at Ohio State University. In 1976 he was hired as a specialist in Plant Virology by USDA-APHIS and was located at the National Plant Germplasm Quarantine Center in Beltsville, Maryland. Dr. Foster is presently responsible for the diagnosis on submitted samples and staff assignments on imports, exports and domestic programs concerning fruit pathogens.

IMPORTATION OF *RIBES* FOR PROPAGATION IN THE UNITED STATES

Joe A. Foster, National Plant Germplasm Quarantine Center, Bldg. 580, BARC-E, Beltsville, MD 20705.

At the beginning of this century, the United States had no federal laws regulating the importation of plants or plant parts. The introduction of some devastating insects and pathogens at this time demonstrated the consequences of unrestricted entry of foreign plant material. In an effort to prevent future damage to U.S. crops, Congress passed the Plant Quarantine Act of 1912.

One of the pathogens that inspired this legislation was the white pine blister rust fungus (*Cronartium ribicola* J.C. Fisch.), which had been damaging native white pines since its discovery in New York in 1906. Since this rust produces its uredinial and telial stages in *Ribes* species, the importation of *Ribes* into the United States was prohibited by the Plant Quarantine Act. During the decades following its discovery, white pine blister rust spread throughout the range of the white pine in the United States and Canada. Research on this pathogen demonstrated that pines could only be infected from spores produced on *Ribes* species. Consequently, the eradication of *Ribes* species near valuable white pines was instituted as a control measure. By 1942, *Ribes* eradication was being used to control rust in designated areas of 20 states. The control of rust within these areas was a state or local responsibility. However, the prohibition on importing *Ribes* enforced by the federal government became pointless after the pathogen had spread across the country. By 1980, the prohibition of *Ribes* because of white pine blister rust was dropped from the U.S. plant quarantine regulations.

In place of the regulation against white pine blister rust, the 1980 revision of the U.S. plant quarantine regulations instituted a prohibition on vegetative propagules of *Ribes nigrum* from Australia, British Columbia (Canada), Europe and New Zealand to prevent the entry of black currant reversion agent. However, even though black currants were prohibited entry in commercial quantities from these areas, small samples of *Ribes nigrum* germplasm could still legally enter the U.S. for scientific or educational purposes after pathogen tests during quarantine did not detect the reversion pathogen or any other foreign pests. Black currants from other countries, red currants, white currants, and gooseberries imported for propagation must be inspected for pests during two growing seasons in postentry quarantine. This regulation to protect domestic currants seemed to anticipate a future expansion of currant cultivation in the U.S. and targeted virus and virus-like pathogens as a major threat to this industry.

A review of these regulations in 1987 revealed some reports of reversion in *Ribes* species other than *R. nigrum* and no substantiated reports of the occurrence of reversion in Australia, Canada or New Zealand. Inquiries requesting information on the occurrence of black currant reversion were sent to plant protection officials in each of these countries, but none of the respondents reported the presence of this disease in their country. At the present time, the U.S. plant quarantine regulations are being revised to expand the prohibition on commercial shipments to all *Ribes* species and to limit the prohibition to only those countries where black currant reversion is known to occur.

Dr. Adam Dale began his small fruit breeding career at the Scottish Crop Research Institute where he worked on *Rubus* and *Ribes* from 1974 to 1983. Since then he began work for the Horticultural Research Institute of Ontario (Provincial Government). His present assignment includes the cultural management of small fruit crops and *Fragaria* breeding.

BLACK CURRANT POTENTIAL IN NORTH AMERICA

Adam Dale, Horticulture Research Institute of Ontario, Box 587, Simcoe, Ontario N3Y 4N5, Canada.

Black currants are widely grown in Europe. Although there is considerable interest, the crop has never had a major impact in North America. This is partly due to regulations which have prohibited growing the crop in the United States, to several diseases which have made the crop difficult to grow, and possibly the overwhelming popularity of *Citrus* juices.

With increasing interest in the crop, it is now a suitable time to revise its prospects on this continent. This paper will summarize the major factors which limit the introduction of the crop to North America and indicate the areas that must be developed before the crop can become commercial.

Regulatory Control

At present, there are large differences in the control of importation of black currants into North America. In Canada there are no restrictions on the importation of material from anywhere in the world. All that is needed is an import certificate and a phytosanitary certificate and absolutely no soil attached to the plants. They are then treated as any common nursery stock and no special declaration is required. In the United States, black currants are prohibited from Europe because of the endemic problem of reversion. Within the United States, there are state regulations which prohibit black currants from being grown in may states. These regulations are in place because black currant is the alternate host for white pine blister rust.

I feel that it is now appropriate to consider the various government regulations with a view to revising them.

There are several factors which are common to both Canada and the United States. These are:

1. Black currants are native in Canada and the United States and are a world genetic resource.
2. White pines are native in Canada and the United States.
3. White pine blister rust is endemic both in Canada and the United States.
4. There is no black currant gall mite or reversion in North America.
5. The two countries have a common seaboard.

6. The Canada/U.S. Free-Trade Agreement committed both countries to harmonizing quarantine regulations.

In addition, in Canada, because there are no restrictions there is a risk that reversion disease may be brought into the country.

Also, white pine blister rust is now of less concern in the highly competitive lumber industry as there are now considerably fewer acres of white pines. In the United States, there is confusion between the horticultural industry, scientists and APHIS (Animal and Plant Health Inspection Service) over importation of black currants. This has led to black currants being imported illegally from Canada into the United States. Also, there is still paranoia over white pine blister rust.

The regulations which control the imports of black currants into Canada and the United States should be harmonized to allow for minimal risk of introduction of reversion and to allow entry of elite germplasm so that the potential of a black currant industry can be realized. Both countries should prohibit importation of material that is going directly to grower fields. However, entry of small quantities of material should be permitted to scientists at established research stations and universities. This material could then be post-entry quarantined at these research locations. As reversion is restricted to *Ribes*, these stations would have effective isolation and miticides could be used to ensure that there were no black currant gall mite infestation. The post-entry quarantine would include an inspection at flowering time as this is the most suitable time to identify any reverted plants.

With these regulations, it should be possible to allow the free movement of black currants within Canada and the United States. The regulations in the United States against white pine blister rust are now becoming academic as there are effective ways to control the spread of the rust using culture and varieties.

Production, Uses, and Potential

The world production of black currants in 1987 was about 568,300 metric tons, all but 3,000 metric tons being grown in Europe. The two largest producers were Poland with 180,000 metric tons and West Germany with 130,000 metric tons. Production in North America is minimal. At the present time there are about 40.5 hectares of black currants grown commercially in Canada and I am aware of none in the United States.

About 90% of the black currant production worldwide is processed into juice. This juice is high in vitamin C. Indeed, fresh black currant fruit contains about three times the vitamin C of oranges. Other uses of black currants include jams and preserves, pie-fillings, yogurt, ice-cream, mineral water, flavorings, teas, liqueurs, and perfumes. The seed is also high in gamma-linolenic acid which is reputed to have pharmaceutical properties.

Presently, black currant products are found in the supermarkets in Canada. A recent survey of my local supermarket found black currant juices and mineral waters, jams and teas on the supermarket shelves. The major juice concentrate "Ribena" was bottled in Ontario and the supermarket has been carrying its own proprietary brand of jam for at least the last nine years.

Clearly, there is a demand for black currant products in Canada. At the present time these are either imported directly or made from imported fruit. The major market appears to be the juice market, as in Europe, and an initial projection suggests that over 8100 hectares of black currants would be needed to capture 1% of the North American juice market.

Major Problems

In the absence of reversion disease, there are four major production related problems of immediate concern to black currant growers in North America. These are: white pine blister rust (*Corartium ribicola* Fisch.), Powdery mildew (*Sphaerotheca mors-uvae* [Schw.] Berk.), spring frost injury and premature fruit drop. Mildew is probably the most serious problem limiting the growth of black currants, and as there are no effective registered fungicides, the only way to control the problem is to use resistant cultivars. Similarly with the other three problems, the major answer is to use resistant or tolerant cultivars. Also, white pine blister rust can be avoided by planting black currants away from five-needle pines.

Cultivars

New cultivars which would be suitable for North American black currant plantations would need to be resistant to mildew and have consistent yields. From trials in Ontario, there are five cultivars which have shown good potential. These are ‘Ben Alder’, ‘Ben Sarek’, ‘Ben Tirren’, ‘Ben Nevis’, and ‘Blackdown’. Of these, the first three have very strong resistance to mildew while in the latter two, the resistance will break down. ‘Ben Sarek’ and ‘Ben Nevis’ also have the added advantage that they have resistance to white pine blister rust.

Presently, discussions are being held with the various plant patent rights holders to obtain permission to propagate these cultivars in Canada. We hope that we will have material available to the growers by 1995.

Summary

To encourage a viable black currant industry in North America initially requires these three steps: the revision of government regulations, selection of new suitable cultivars and the development of a propagation industry. The initial steps towards these three requirements have been made and provided they can be successfully concluded there is potential for a new industry to develop.

The next phase once we have a small viable industry will be to promote a marketable crop. This will require major effort as the North American consumer is not familiar with black currants. It will take much to persuade the North American consumer that black currant juice is an acceptable alternative to *Citrus* juice.

Garry Wood is the scientific officer at the Horticulture and Food Research Institute of New Zealand Ltd. This was formerly called the Department of Scientific and Industrial Research (DSIR). He has worked there since 1959. His worked centered extensively on virus and virus-like diseases of pome and stone fruit trees occurring in New Zealand. More recently he has taken on an assignment on virus and virus-like diseases of small fruits. He also has input concerning the study of viruses of grapes and citrus. He has worked extensively with the quarantine of imported plants with virus diseases.

RIBES PERSPECTIVE FROM NEW ZEALAND

Garry A. Wood, The Horticulture and Food Research Institute of New Zealand, Private Bag 92169, Auckland, New Zealand.

In comparison to some other fruiting crops, the growing of *Ribes* crops is only a small industry in New Zealand. Black currant growing is confined to the South Island. Most are grown in the southern most areas of Southland and Otago, with smaller quantities being grown in the Canterbury and Nelson districts. Very few red currants are now grown and these are confined to the southern areas of the North Island, and in Canterbury. There was a small gooseberry industry located mainly in the southern areas of the North Island, and in Canterbury, but this was largely destroyed in 1985 by the arrival of gooseberry mildew in New Zealand. The gooseberry industry is slowly reviving with the planting of the mildew resistant 'Invicta' cultivar.

Almost all *Ribes* cultivars grown in New Zealand have been imported from the Northern Hemisphere. Most of them have come from England, Scotland and Europe. *Ribes* imports were grown under quarantine conditions from the early 1950's. However, testing for virus infection by the use of indicator cultivars did not commence till 1970. Thus it is likely that the diseases of a virus or virus-like nature which are present in New Zealand were probably imported with several cultivars in early importations. As yet, only two diseases of a virus or virus-like nature are known to occur in New Zealand, these being reversion of black currants (Wood et al. 1990) and vein banding of red currants (Wood 1991). A variegation disorder occurs in some black currant cultivars (Wood 1991). Tomato ringspot virus was found in an imported red currant cultivar (Fry & Wood 1978), and cucumber mosaic virus in a newly imported black currant cultivar (Wood 1989), but all plants of these have been destroyed.

Black Currant Reversion

Incidence in New Zealand

Until the 1980's, incidence of black currant reversion was thought to be low in New Zealand. Subsequently, increasing reports of possible infection in the South Island were investigated. Testing showed reversion to be widespread on commercial properties in both Otago and Southland. In Canterbury and other areas where black currants are grown, it appears to be of low incidence. Cultivars so far found infected are 'Cotswold Cross', 'Daniel's September', 'Kentish Hero', 'Magus', 'Seabrooks Black', and 'Topsy'. 'Magnus' is the most widely grown and most commonly infected cultivar.

Symptoms

The flower bud, leaf edge serration, and crop reduction symptoms of reversion which have been found in the field and in transmission experiments appear similar to those described for the common forms of reversion occurring in England and Western Europe. In graft transmission tests with 'Baldwin' indicator in Auckland, the sepals of affected flower buds were less hairy than normal and brighter in color. The brighter color of the affected sepals were not as conspicuous as described overseas. This may have been because of the lack of sufficient winter chilling in Auckland, as sepals of infected plants in Otago and Southland are conspicuously red.

Following graft inoculation, leaves of the new shoot growth of affected reversion indicator cultivars showed reduced serrations on the leaf margins and elongated centre lobes typical of reversion. A few of the lower leaves showed the chlorotic vein pattern symptom of reversion. As black currants do not fruit readily in Auckland because of lack of winter chilling, it was not possible to assess the effects of reversion on the fruit or fruit production. However, reversion has caused a marked reduction in fruiting on some affected South Island commercial properties. On other properties, cropping levels can be acceptable where reversion is present.

The severe form of reversion in Finland, causing malformed flowers, has not been found in New Zealand.

Experimental transmission

'Baldwin' has been suggested as a suitable indicator for reversion, and in 1988, material of 'Baldwin' was obtained from the Institute of Horticultural Research at East Malling in England. In the season following graft inoculation of container-grown plants, typical flower bud and foliage symptoms occurred. Positive transmission of reversion was obtained from the cultivars 'Daniel's September' from Otago, and 'Cotswold Cross' and 'Seabrook's Black' from Southland. Subsequently, using the same source of infection, graft-transmission was obtained in the cultivars 'Silvergieters' and 'Ojebyn', both of which have been found to be sensitive to reversion overseas.

Spread of infection

In the field, the use of infected cutting material in the propagation of new plants has probably accounted for much of the spread in New Zealand plantings. In addition, investigations in England have shown the black currant gall mite (*Cecidophyopsis ribis*) to be a vector of reversion.

In New Zealand, the gall mite is widespread in black currants, especially in southern districts, and is likely to be responsible for further spread of infection here.

The gall mite is an extremely small, sausage-shaped mite which invades the healthy buds of black currant. Within the buds, the mites feed and multiply, causing major developmental

changes to the leaf and flower primordia, resulting in the enlarged, swollen bud condition commonly known as "big-bud." High infestations can seriously deplete expected yield from plants through the destruction of buds.

Overseas literature indicates that the adult mites leave the swollen, infected buds in spring when the temperatures are above 13°C. They move into newly developing buds during their formation in late spring and early summer. The mites disperse by crawling from one bud to another, or they may be blown by the wind or carried by insects and birds. Egg laying and mite nymphal development take place in the newly infested buds during summer and autumn. Overseas records show one breeding peak for the mites in autumn when infested buds swell, and another in mid to late winter. Mite infestations in buds increase from just a few mites per bud in early summer to populations of more than 20,000 per bud the following spring. As the infested buds start to dry out in spring, large numbers of the mites collect on the outer bud scales of an infested bud. When temperatures are suitable, they disperse to other newly formed buds.

In New Zealand the population development for the species follows this general pattern, but important differences in the development and the life cycle of the mite have been noted. Firstly, the major dispersal period in spring varies considerably between the black currant producing regions, for instance, Southland and South Canterbury. Secondly, substantial development of infestations can occur in early summer, so that new buds heavily infested and swollen by January and February release a proportion of their mites during this period for later infestation of new buds. Evidence suggests that this occurs on warm days during most of the autumn, through to early June. Some swollen green buds may be virtually empty by June; the adult mites have dispersed by then.

Sampling of infested and apparently uninfested buds as late as May has shown that some apparently uninfested buds do contain new infestations of mites, which develop into major infestations quite late into spring and early summer.

It appears that the situation in New Zealand is complex and the mite may be quite difficult to control because of this. Current research is aimed at investigating control of the species.

Control Measures

Recommended control measures for reversion in New Zealand are as follows:

<u>Old blocks</u>

Degree of reversion: Expression of symptoms can vary in black currants from a single shoot on one branch, to several or all branches of the whole bush.

Where infection is at a low level in a block, it may be practical to remove infected bushes. Recommendations are to cut off infected bushes at ground level and carefully spray the regrowth about one month after cutdown, with the herbicide Metsulfuron methyl. All the wood removed

should be burnt as soon as possible after removal. However, in most cases so far found, the level of reversion in old blocks is more than just occasional plants, which does not make removal of single plants a practical proposition. Growers are generally of the opinion that it makes little sense from a practical point of view to attempt to rogue bushes in blocks which have been established for more than 8 years.

Where, as a result of reversion, whole blocks have levels of production close to the costs of production, they should be removed, as they will pose a continual source of infection for all neighboring blocks, especially those downwind. Removal of these blocks should be achieved by cutting off the bushes at ground level and then ploughing out the stumps with a swamp plough. Alternatively, the old plants can be allowed to regrow after removal of top growth and then sprayed with Metsulfuron methyl before ploughing. Grubbers should be used to keep the old stumps from regrowing for about 2 months after removal. As much material as possible should be burnt.

Young blocks (up to 3 years old)

In situations where young blocks have been planted in areas close to an infected planting, or where previously infected areas have been removed, considerable emphasis should be placed on checking them for infection. Any plants found to be infected with reversion should be removed, except where this exceeds 20% of the total plantings, in which case the policy suggested for old blocks should apply.

Replanting

Circumstantial evidence suggests that there is some suppression of growth where black currants follow black currants as a crop. Where possible, replanting of previously reverted blocks should be avoided; but where this is not possible, blocks should be fallowed for at least 12 months. During this fallow time the area should be checked and any regrowth or seedlings should be dug out or killed with Metsulfuron methyl.

Planting material

All new planting material should be obtained only from properties where the owner is very confident of freedom from reversion and gall mite infestation. The level of incidence should be such as to refund all plant material and freight costs if a single galled bud is found on new planting material.

Replacement cultivars

There is still considerable work to be done with assessment of the gall mite resistant cultivars before there can be confidence that these will crop at acceptable levels, and have a confirmed place in the marketing mix of the industry of the late 1990's, when full production is expected to commence. Plants of 1707/47 have been distributed to five growers as small plants this

season. 'Pilot Alexandra Mamkin', which is still showing complete resistance to reversion, has also been distributed to one grower, who now has sufficient material for a small commercial planting. A trial has been established in Southland for gall mite resistant selections of black currant obtained from East Malling, England, which supplements the previously planted trial block at the Canterbury Research Centre, Lincoln.

Red Currant Vein Banding

Incidence in New Zealand

As red currants are not grown widely as a commercial crop in New Zealand, the reported incidence of red currant vein banding has been low. Infection has been found near Levin, in the cultivars 'Gonduin', 'Jonkheer van Tets', and 'Stanza'. Vein banding symptoms have not been reported on gooseberry in New Zealand. Few gooseberries are now grown, because of the yield-reducing effects of American gooseberry mildew *Sphaerotheca mors-uvae* (Schweinitz).

Symptoms

The red currant cultivars 'Gonduin', 'Jonkheer van Tets', and 'Stanza' showed a pale green or light yellow banding or clearing of the smaller veins of the leaf, giving the leaves a net-like pattern. Graft-inoculated red currant seedlings showed similar symptoms. The symptoms were most pronounced on leaves produced early in the season, and leaves produced later in the season often did not show symptoms.

Experimental transmission

In New Zealand, transmission of vein banding was achieved by grafting scions of infected red currant cultivars to container-grown red currant seedlings. Symptoms appeared on the seedling leaves in the season following graft inoculation. In 1987, an indicator of gooseberry vein banding, B1385/81. was obtained from the Institute of Horticultural Research at East Malling in England. In graft-transmission trials with this indicator in New Zealand, vein banding symptoms occurred two seasons after grafting with infected 'Jonkheer van Tets'.

Spread of infection

Natural spread of infection has been reported in red currant overseas. Because of the small quantity of red currants grown commercially in New Zealand, natural spread of vein banding is likely to have been slow, if it occurred at all. One of the reported aphid vectors of veining banding, *Hyperomyzus lactucae* L., is present in New Zealand, but its involvement in the spread of the disease has not been investigated.

Control measures

Because of the low incidence of vein banding, and the small number of red currants grown commercially, no specific efforts have been made to investigate control. If the planting of red currants were to increase markedly, the planting of healthy material and removal of any adjacent infected stock would be recommended.

Disorder

Infectious variegations of black currants

A disorder of black currants, "infectious variegation" or "gold dust," is present in New Zealand. In England, infectious variegation has been reported as graft-transmissible. However, there is still doubt as to whether or not it is a graft-transmissible disease. In New Zealand, several black currant cultivars have been found with the variegation symptom. All plants of 'Daniel's September' appear to be affected, as do all plants of 'Pinelands', a local cultivar thought to be a sport of 'Daniel's September'. Field crops of 'Pinelands' in Canterbury have in some seasons shown conspicuous symptoms of variegation. Attempts to eliminate this variegation from 'Pinelands', using heat therapy, have been unsuccessful, and attempts to graft-transmit it to other cultivars gave inconclusive results. Thus in New Zealand, as in England, there is still doubt if variegation is graft-transmissible.

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Rex Brennan studied plant pathology at the University of Manchester. After obtaining his doctorate he worked for six years for a private plant breeding company in England. He began an assignment in *Ribes* breeding at the Scottish Crop Research Institute in 1986. His other interest include *Vaccinium* and other bush fruits, although his main assignment is *Ribes*.

RIBES BREEDING IN THE UNITED KINGDOM

Rex M. Brennan, Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA, Scotland

The breeding of *Ribes* fruits, particularly black currant (*R. nigrum* L.), has been in progress at the SCRI for approximately 30 years. During this time, a range of cultivars have been released that now occupy around 80% of the United Kingdom (UK) hectarage and also enjoy considerable popularity across Europe and beyond. While Ben Lomond occupies most of the UK hectarage, more recent releases such as Ben Tirran are now beginning to increase their market share.

Since the program began, the primary objectives have altered and expanded to encompass changes in growing practice as well as advances in available technology. Originally objectives were concentrated on the introduction of genes imparting improved tolerance of damaging spring frosts during the flowering period, both by increasing the physiological hardiness of genotypes and by delaying the flowering process for frost escape. This line of work led to the introgression of genes from Scandinavian and Soviet germplasm.

However, although improved low temperature tolerance is still a high priority within the SCRI program today, the program's objectives are characterized by a greater emphasis on pest and disease resistance and resistance to gall mite [*Cecidophyopsis ribis* (Westw.)] and reversion are the leading areas.

The increased importance of this pest/disease complex in the UK and throughout Europe has always seriously threatened the economic production of black currant, but control of the mite is now difficult, involving repeated sprays of the organochlorine acaricide endosulfan. This chemical has proved to be of limited efficacy as well as environmentally undesirable, and although a number of other compounds, including the synthetic pyrethroid fenpropathrin, have been assessed as possible alternatives, the breeding of resistant cultivars offers the only long-term solution to this problem.

No commercial black currant cultivars presently available in the UK are resistant to either gall mite or reversion, although no evidence for increased susceptibility of modern cultivars has been presented. However, there are several sources of resistance available elsewhere in the *Ribes* genus. In the case of gall mite, the one that has been most widely used at SCRI is resistance from *R. grossularia* L. based on the single dominant gene *Ce*. Backcross seedlings incorporating this resistance have been identified from infestation plot studies, and several seedlings, mainly (BC) backcross generation 5 and BC6, are undergoing evaluation in field trials.

In breeding for resistance to *C. ribis*, evaluation of progenies segregating for resistance normally involves the use of field infestation plots with mite-infested spreader plants. However, this technique is time consuming, taking a minimum of three years and carries inherent risks of uneven mite pressure across the plot. Work at SCRI to develop a reliable, rapid laboratory-based screening technique expanded on earlier work by Austin et al. (1983) using metabolic profiling to separate resistant and susceptible genotypes. By examining the terpenoid composition of buds from black currant genotypes of known resistance or susceptibility, including segregants from the same progeny, by capillary gas chromatography it is possible using discriminate analysis to link the terpenoid chemical 'profile' of a genotype to its resistance status (Brennan et al., 1992). The use of metabolic profiling in this way was successful in 88% of the genotypes examined, giving good prospects for the use of this technique in preference to, or in combination with, field assessment protocols.

A further resistance gene, *P*, derived from *R. nigrum* var. *sibiricum* (Wolf.), has also been used for mite resistance at SCRI, although the resistance conferred by this gene appears to allow mite survival for sufficiently long to transmit reversion (Anderson, 1971) before necrotic tissues develop. In many respects, the resistance from *R. nigrum* var. *sibiricum* is easier to work with, involving less transfer of undesirable characters in terms of fruit quality and low temperature tolerance. However, the use of resistance *Ce* offers better prospects at the present time in the SCRI program.

Resistance to reversion has been incorporated into the SCRI germplasm via *R. dikuscha* and its derivatives, notably the Russian cultivar 'Golubka'. The inheritance of this resistance is not very clear, however, and the segregation ratios from different progenies are shown in Table 1. From the progeny of Ben Alder x Golubka, a reversion-resistant segregant has proved very promising in preliminary trials, with good overall agronomic qualities. This seedling, F4/1/67, is currently undergoing further trials prior to possible commercial release.

Identification of reversion-resistant segregants presents similar problems to those for gall mite-resistant segregants, in that a lengthy processing of grafting, back-grafting and slow symptom expression are involved. Increasingly, breeders at SCRI and elsewhere are using marker-based selection protocols to rapidly identify plants with desirable characters at the earliest possible stage of development. The use of isozyme analysis in *Ribes* has proved problematic, with generally insufficient polymorphism to be useful as markers. However, initial indications with molecular markers such as RFLPs and RAPDs are that the movement of desirable traits, including gall mite and reversion resistance and other polygenic characters, within the breeding program will be effectively monitored by these means.

Protocols for the *Agrobacterium*-mediated transformation of black currant have been developed at SCRI (Graham & McNicol, 1991), and the production of transgenic black currants in the future is limited only by the availability of appropriate genes for incorporation. Studies currently in progress include the insertion of pest resistance genes such as the cowpea protease trypsin inhibitor (CpTi) gene, coding for an antimetabolite to a wide range of Lepidopteran and Coleopteran pests. As useful genes become available, they will be incorporated into the

available *Ribes* germplasm, and useful genes, once identified, may be isolated and cloned for future insertion, in conjunction with the marker development studies.

Within the *Ribes* genus, alternative sources of resistance to gall mite and reversion remain unexplored, although the development of new technology makes their future exploitation increasingly likely. In any interspecific hybridization, however, the end result must be a genotype that fits into the specific commercial requirements of the industry, in both agronomic and quality terms. In the UK the majority of the black currant crop is grown under contract for the production of juice by SmithKline Beecham, who sponsor the SCRI breeding program. The use of *R. grossularia*, for example, causes a reduction in juice quality, frost hardiness and bush erectness that is only overcome by a long-term backcrossing program to regain an acceptable form. The use of molecular and cellular techniques in conjunction with classical breeding can only hasten the production of agronomically-superior, mite and reversion-resistant cultivars that the *Ribes* industry worldwide needs urgently.

Anderson, M.M. 1971. Resistance to gall mite (*Phytoptus ribis* Nal.) in the Encoreosma section of *Ribes*. *Euphytica* 20:422-426.

Austin, D.J., Hall, K.J., Keep, E. & McFie, H.J.H. 1983. Metabolic profiling as a potential aid to blackcurrant breeding. *Proc 10th Int'l Congress of Plant Protection, Brighton 2:825.*

Brennan, R.M., Robertson, G.W., McNicol, J.W., Fyffe, L. & Hall, J.E. 1992. The use of metabolic profiling in the identification of gall mite [*Cecidophyopsis ribis (*Westw.)]-resistant blackcurrant (*Ribes nigrum* L.) genotypes. *Ann. Appl. Biol.* (in press).

Graham, J. & McNicol, R.J. 1991. Regeneration and transformation of *Ribes*. Plant, Cell, Tissue and Organ Culture 24: 91-95.

Ian Roberts, Principal electron microscopist, with 28 years experience, in the Virology Department of the Scottish Crop Research Institute, Invergowrie, Dundee, Scotland. His main interests cover ultrastructural effects of infection with viruses and virus-like agents in plants and vectors, detection of virus particles in plants and vectors, and serological techniques for electron microscopy including, immuno-gold labelling and location of epitope sites on virus particles.

ULTRASTRUCTURE OF THE BLACK CURRANT GALL MITE, *CECIDOPHYOPSIS RIBIS*

Ian M. Roberts, Principal Electron Microscopist, and A. Teifion Jones, Plant Pathologist, Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland.

In one of a number of different approaches to identify the agent of reversion disease of black currant, the ultrastructure of infected plants and of the gall mite vector, *Cecidophypsis ribis*, feeding on such plants, is being studied. The objective of this approach is to try to identify any structures resembling known or novel pathogenic organisms in plant and vector tissues. In studies with the mite vector, it was first necessary to accurately determine the internal anatomy of the animal in order to identify and locate the feeding apparatus and food canal, areas where the reversion agent is most likely to be present. Detailed information on the anatomy and ultrastructure of eriophyid mites is sparse and little information is published for *C. ribis*. This paper therefore reports on our preliminary studies to identify the major anatomical features of this vector mite.

Methodology

Mites from galled black currant buds, both from reverted and healthy plants, were extracted in 0.01% Triton X-100 and centrifuged for 15 min at 1000 g. The supernatant fluid was decanted off and replaced with 1% gluteraldehyde in PIPES buffer, pH 8.0. After 1h, the suspension was centrifuged again, the supernatant decanted off and replaced with warm 1% agar and immediately poured on glass slides and allowed to cool. Pieces of agar containing several hundred discretely embedded mites were processed further for electron microscopy using previously described protocols (Rasseas et al. 1989), and embedded in Araldite resin. Single adult mites were orientated and sectioned at 5-10 μm as examination centered on the food pump and stylet canals.

Figure 1. Scanning electron micrographs of a section through a galled black currant bud showing the general size and external morphology of eggs and adults of *Cecidophyopsis ribis*.

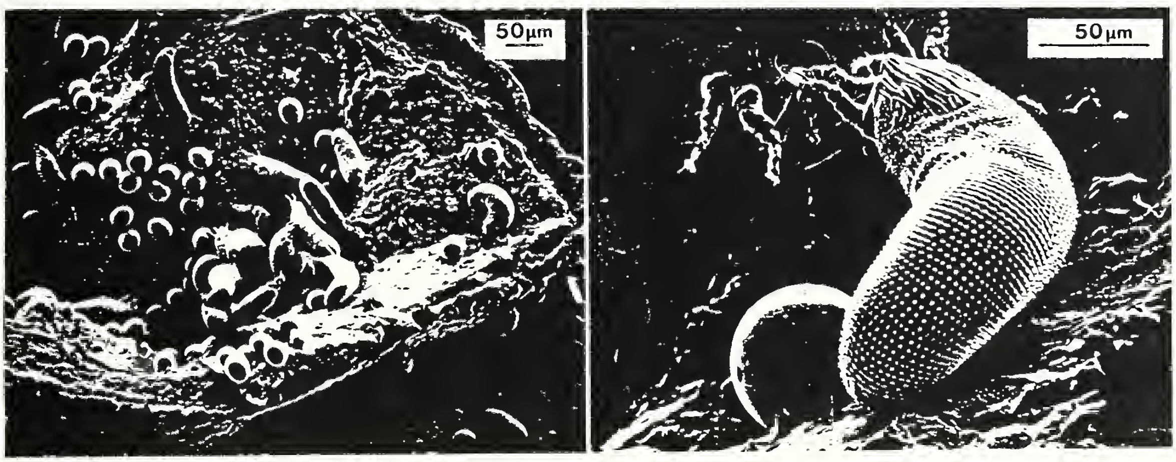
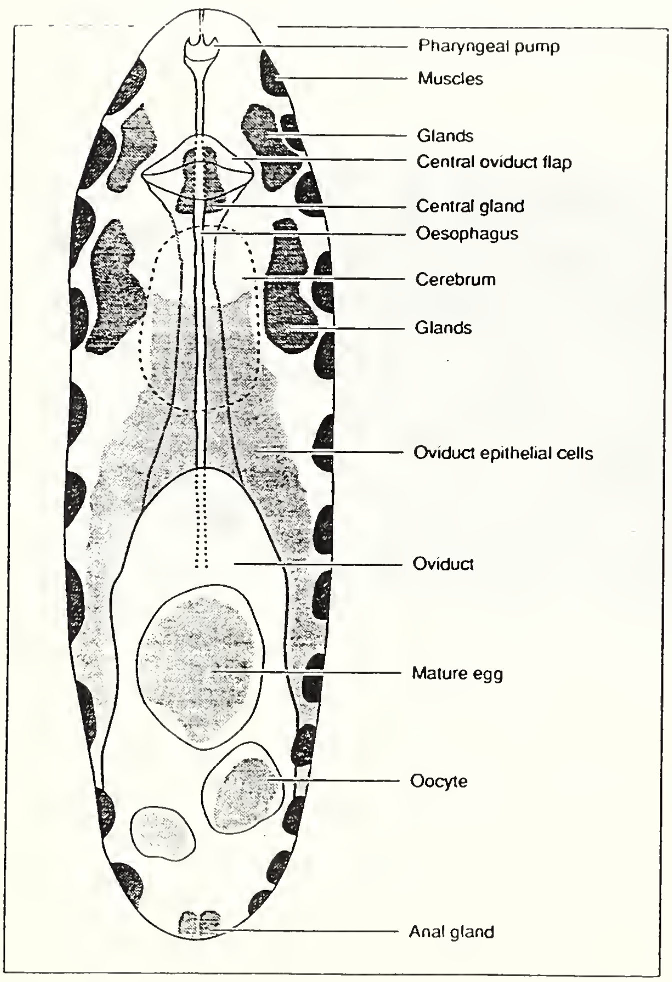


Figure 2. Diagrammatic representations of the anatomical structure of *Cecidophyopsis ribis* when viewed (a) ventrally and (b) laterally, based on electron-microscopy of serial sections of the mite.

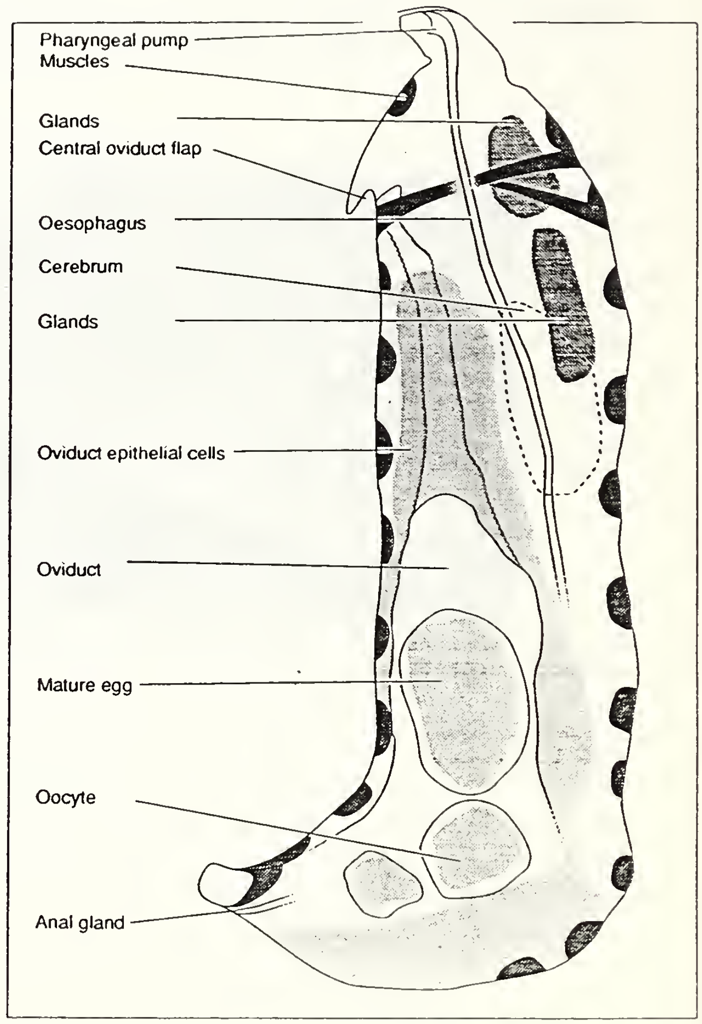
Figure 2 a



Cecidophyopsis ribis

Ventral view

Figure 2 b



Cecidophyopsis ribis

Lateral view

Results and Discussion

The general external morphology and size of *C. ribis* are shown in Figure 1. Prior to the dehydration steps, mite morphology was unchanged but, after dehydration, some shrinkage of the body region behind the genitalia occurred. Nevertheless, the internal body structure seemed intact except near the tail-end of the oviduct, where fixation seemed less satisfactory. Based on evidence from the serial sections, the main anatomical features of the mite were identified and the composite picture they provided is illustrated diagrammatically in Figure 2. These features are similar to those reported for the few other eriophyid mites that have been studied in detail (Nuzzaci 1976).

The region immediately before and after the pharyngeal pump was examined in detail. While it was possible to trace the very narrow oesophagus for about half the length of the animal, the structure apparently disappeared at, or near, the oviduct, and no connection to the anus was traceable. Very little material seemed to be retained within the food canal in any of the mites examined. This was probably due to the fact that in all specimens examined the pharyngeal pump was in the closed position. Presumably, this occurred during primary fixation and, as a consequence, material within the stylet canal was expelled. If this proves to be a feature of the other specimens to be examined, it decreased greatly the prospect of identifying the reversion agent in this region of the mite.

Acknowledgements

We thank our colleagues: E. Milne for skilled technical assistance, G. Duncan for the scanning electron micrographs, S. Gordon for some mite samples and discussions on handling mites, and Dr. J. Amrine, West Virginia State University, for helpful discussions on mite structure.

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R. William Doerner is an Agricultural Science Research Technician at the USDA-ARS National Clonal Germplasm Repository in Corvallis. He oversees the Integrated Pest Management Program at the facility.

Joseph Postman is the Plant Pathologist for the USDA-ARS NCGR Corvallis. He has worked at the repository since 1981. He supervised the pathogen testing and elimination program for all clonal germplasm in the Repository collection.

ERIOPHYID MITES ON *RIBES*

Bill Doerner and Joseph Postman, USDA-ARS NCGR, 33447 Peoria Road, Corvallis, OR 97333-2521 USA.

Eriophyid mites (*Eriophyoidea: Acari*) are important pests of many different plants. Their feeding often produces bizarre and complex structures on plant tissue such as leaf and bud galls, leaf rolls, erineum, and witches' brooms. For this reason, they are commonly referred to as gall, rust, bud, or blister mites depending on the host reaction to their feeding. Eriophyids are tiny mites almost invisible to the unaided eye. They are specialized feeders with a narrow host range. Eriophyids are unique among mites in that they only have two pairs of legs. In addition to being important plant pests, they are also capable of vectoring viruses and other plant diseases. Eriophyids are the only mites known to transmit plant viruses.

In the spring 1991, unusual leaf symptoms were observed on a gooseberry, *Ribes curvatum* Small, in the *Ribes* field collection at the Germplasm Repository in Corvallis, Oregon. The symptoms observed included: blister-like enations along with some tissue necrosis on the upper leaf surface near the junction of the petiole and the base of the leaf. Upon closer examination of the leaves under a dissecting scope, a number of eriophyid mites were observed moving slowly in and around the "caverns" between the main veins on the underside at the base of the leaf.

Samples of the mite and the leaf symptoms were sent to USDA-APHIS for identification. The mites were initially identified as *Cecidophyopsis ribis* (Westwood). Subsequently, a thorough survey of all *Ribes* material at the repository revealed infestation of this foliar mite on 19 plants in the field collection. The mites were found on field gooseberries and on three cultivars of red and white currants which were under post-entry quarantine in our greenhouse. No mites were observed on gooseberries or currants in our screenhouse collection. No mites were found on black currants in any location at the Repository.

In spring 1991, APHIS placed a quarantine on our entire Ribes collection. We uprooted and burned the Repository *Ribes* field collection. We chemically treated infested *Ribes* in the greenhouse. We propagated replacement plants from the clean screenhouse plants to prepare a new field collection. The plant collections were carefully examined in spring and summer of 1992. No foliar mites were observed on any *Ribes* at the Repository in 1992.

Since the initial finding of the foliar mite, the initial identification has been questioned. Dr. Jim Amrine has suggested a new taxon *Cecidophyopsis grossulariae*, adapted from Collinge(1907), as a new species name. The foliar mite has been reported in England (Easterbrook, 1980) although the native or introduced range of the mite has not been confirmed. APHIS has since removed the quarantine imposed on the Repository *Ribes* collection.

Wes Messinger is a Graduate Research Assistant studying Ribes taxonomy at the Oregon State University, Department of Botany and Plant Pathology.

Aaron Liston is an Assistant Professor in the Botany and Plant Pathology Department, Oregon State University. Dr. Liston is the Curator for the Herbarium at OSU.

NUCLEOTIDE SEQUENCE DIVERGENCE IN SIX *RIBES* SPECIES

Wes Messinger, Aaron Liston and Kim E. Hummer, Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR 97331, USA.

Restriction site variation in three DNA sequences amplified by the Polymerase Chain Reaction was examined in six species of west North American *Ribes*. *R. cereum* Doug.(subg. *Calobotrya* Spach), differs in floral morphology from *R. lacustre* (Pers.) Poir., *R. montigenum* McClatchie (subg. *Grossularioides* Janczewski), *R. howellii* Greene, *R. laxiflorum* Pursh, and *R. erythrocarpum* Cov. & Leiberg (subg. *Heritiera* Janczewski). Two chloroplast sequences, (a 4100 base pair region encoding part of RNA polymerase C and a 3200 base pair region encoding part of the large subunit of ribulose 1,5-bisphosphate carboxylase-oxygenase (RUBISCO) and a 2400 base pair region of nuclear ribosomal DNA including the 18s and 5.8s coding regions and the two internal transcribed spacers) were amplified and analyzed for restriction endonuclease site polymorphism. Mean nucleotide sequence divergence between species ranged from 0.21 to 1.3 percent. Considering *R. cereum* the outgroup, two synapomorphies, one in the nuclear rDNA and one in the chloroplast, unite *R. lacustre, R. montigenum* and *R. montigenum* and *R. laxiflorum.*

Summary of Points from Panel Discussion

Panel Members

Dr. J. Amrine, WVSU, Morgantown, West Virginia
Dr. R. Converse, USDA-ARS, Corvallis, Oregon-Moderator
Dr. A. Dale, Ontario Hort. Exp. Station, Simcoe, Canada
Dr. A.T. Jones, SCRI, Dundee, Scotland
Dr. J. Foster, USDA-APHIS, Beltsville, Maryland
Dr. J. Krantz, OSU, Corvallis, Oregon
Dr. V. Trajkovski, Swedish University, Balsgård, Sweden
Dr. G. Wood, Hort. Research Institute, Auckland, New Zealand

Recommendations for Additional Research

Eriophyid Mite

1. Explore the taxonomic differences among Eriophyid mites affecting *Ribes*. Possible application of Random Amplified Polymorphic DNA (RAPD) and Polymerize Chain Reaction (PCR) analysis to differentiate between species.

2. Are Eriophyid mites economically significant in the absence of the reversion disease?

3. Does the morphology of the Eriophyid mites change on different host species?

4. Differences in migration periods in New Zealand suggest a different species.

5. How do the dormant gall mites penetrate buds?

6. Morphology of resistant *Ribes* genotypes.

7. Is plant host resistance against *C. ribis* effective against *C. selachadon* or *C. grossulariae n.sp.*?

8. Additional work on identifying resistant *Ribes* germplasm and developing resistant cultivars.

Reversion Disease

1. What is the causal agent of reversion?

2. There is a need for better, more rapid detection methods.

3. What are the vectoring capabilities of the various eriophyid species?

4. Additional work on identifying resistant *Ribes* germplasm and developing resistant cultivars.

5. Identify extremely susceptible *Ribes* germplasm which may be useful as improved indicator plants.

6. Is resistance against "European" reversion disease effective against "Russian" reversion?

7. Identify effective disease therapy procedures.

Consensus Recommendations

Ribes Risk Assessment Workshop
17-18 August 1992
Corvallis, Oregon, USA

These recommendations for movement of clonal *Ribes* germplasm into the United States were developed through consensus of the workshop participants and relate to vegetative propagules from pathogen-tested stock. Non pathogen-tested stock should continue to be imported through a federal quarantine facility where release is contingent upon a suitable pathogen testing/pathogen therapy program.

1. Pathogen tested stock from reliable sources should be required for importation into Post-Entry-Quarantine.

2. United States - Canadian *Ribes* importation programs should be harmonized with a view to removing plant movement restrictions between the two countries following Post-Entry-Quarantine.

3. Importation should be limited to non-commercial propagation quantities.

4. Post-Entry-Quarantine should be carried out in a containment facility at a recognized university or research institution.

5. Post-Entry-Quarantine *Ribes* plants should be treated with systemic insecticides of proven acaracidal value.

6. More research should be performed concerning identification of effective miticides.

7. Plants should be examined for two years at flowering for reversion disease.

APPENDIX 1. **Alphabetical List of Species Of Eriophyoidea Attacking Ribes:**
Prepared by: Dr. Jim Amrine

ERIOPHYIDAE::

Aceria breakeyi Keifer 1959.

Aceria scaber (Nalepa) 1893.

Aculus mansoni Amrine 1992.

Aculus masseei (Nalepa) 1925.

Aculus ribis (Massee) 1929.

Cecidophyopsis grossulariae (Collinge) 1907.

Cecidophyopsis ribis (Nalepa) 1893.

Cecidophyopsis ribis (Westwood) 1869.

Cecidophyopsis selachodon Eyndhoven 1967.

Epitrimerus sierribis Keifer 1939.

Phyllocoptes bellus (Liro) 1943.

Shevtchenkella neglectus (Massee) 1927.

DIPTILOMIOPIDAE:

Diptacus gigantorhynchus (Nalepa) 1892.

Diptacus pengsonae Briones & McDaniel 1976

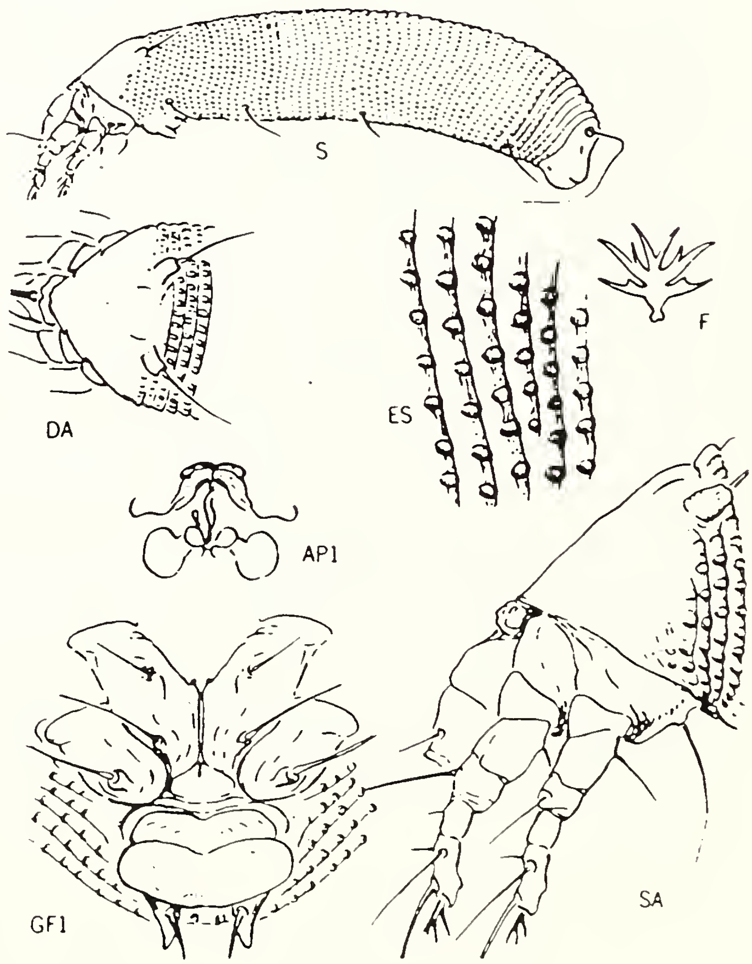
Rhyncaphytoptus tumidus Liro 1943.

APPENDIX 2: **Key to Eriophyid mites attacking *Ribes* spp.**
Provided by: Dr. Jim Amrine

1.	Mites are large and globose with a large rostrum; chelicerae sharply curved at base.....Diptilomiopidae	2
	Mites wormlike or fusiform with normal straight chelicerae.........Eriophyidae..............................	4
2.	Empodium divided..Diptacus...	3
	Empodium simple.Rhyncaphytoptus tumidus Liro	
3.	Empodium widely divided with 3 rays; shield with about 8 irregular cells; occurs on R. missouri ensis..Diptacus pengsonae B. & M.	
	Empodium narrowly divided with 5 rays; shield with 12 or more cells, reported once from R. rubrum...Diptacus gigantorhyncus (Nal.)	
4.	Mites wormlike, elongate; shield without setae........................Cecidophyopsis.........................	5
	Mites wormlike or fusiform; shield with one pair of dorsal tubercles and setae.............................	7
5.	Four rows of coxal-genital annuli, with small microtubercles averaging 5.2, 8.0, 11, and 12.25 per row, anterior to posterior, respectively; foliar mites, usually on Ribes grossularia............... ....Cecidophyopsis grossulariae (C.)	
	Microtubercles on coxal-genital setae are larger, more rounded; on currants................................	6
6.	Coxal-genital microtubercles average 3.8, 4.6, 5.6 and 7.0 per row, anterior to posterior; lateral seta more ventral in location; ventral microtubercles posterior to 3rd ventral setae are easily visible and regular in distribution; on R. nigrum......................................Cecidophyopsis ribis (W.)	
	Coxal-genital microtubercles average 2.8, 4.5, 6.2 and 4.8 per annulus; lateral seta more lateral in position; ventral microtubercles on annuli posterior to 3rd ventral setae not clearly visible and irregular in size and distribution; on R. rubrum............................Cecidophyopsis selachodon E.	
7.	Mites worm-like; shield does not project over base of rostrum; hysterosomal annuli subequal dorso-ventrally...Eriophyinae, Aceria.......................................	8
	Mites fusiform; shield forming a frontal lobe projecting over the base of the rostrum; dorsal annuli larger and fewer in number...................................Phyllocoptinae....................................	9
8.	Shield with median, admedian and submedian lines well developed; genital coverflap with several longitudinal lines; foliar deformation of R. nigrum and R. rubrum in Europe......Aceria scaber (N.)	
	Shield with posterior traces of admedian lines only; genital coverflap without longitudinal lines; causes erineum on Ribes divaricatum in California......................................Aceria breakeyi K.	
9.	Lateral margins of dorsal hysterosomal annuli project laterally; dorsal tubercles on posterior margin of shield, directing setae posteriorly.............................Schevtchenkella neglectus (M.)	
	Lateral margins of dorsal hysterosomal annuli evenly rounded; dorsal tubercles variable.................	10
10.	Dorsal tubercles ahead of rear margin of shield..	11
	Dorsal tubercles on rear margin of shield, directing setae posteriorly................Aculus................	12
11.	Dorsal hysterosoma with well developed middorsal ridge; vagrant on Ribes nevadense in California.. Epitrimerus sierribis K.	
	Dorsal hysterosoma evenly rounded; vagrant on Ribes alpinum in Finland...Phyllocoptes bellus (L.)....	
12.	Admedian lines of shield well-developed, converging anteriorly and projecting onto the frontal lobe; vagrant on Ribes nigrum, R. rubrum and R. alpinum in Europe................Aculus ribis (M.)	
	Admedian lines less well-developed, do not strongly converge anteriorly and do not reach the frontal lobe..	13
13.	Weak median and admedian lines present on shield; 30-40 dorsal hysterosomal annuli; vagrant on Ribes nigrum, R. alpinum, R. grossularia, and R. rubrum in Europe.........Aculus masseei (Nal.)	
	Shield with weak admedian lines only, strong lines parallel to shield margin; 17-21 dorsal hyster-osomal annuli; occurs on Ribes nigrum in New Zealand...............................Aculus mansoni A.	

APPENDIX 3: **Alphabetical summary of eriophyid mites reported in *Ribes***
Compiled by: Dr. Jim Amrine

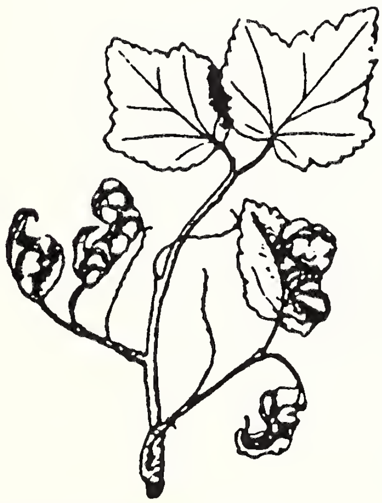
Aceria breakeyi Keifer 1959.
Synonymy: none.
Previous assignment: Aceria.
Host: Ribes roezlii (Grossulariaceae).
Host common name: Sierra Gooseberry.
Alternate host(s): Ribes divaricatum (Coastal Black Gooseberry).
Habit: erineum.
Type locality: California, USA.
Reference: Keifer 1959, E. S. 26, Bull. Cal. Dept. Agric. 47: 272 (no figure); also, Keifer et al., 1982, USDA, ARS, Agr. Handbook No. 573: 68-69, pl. 27.



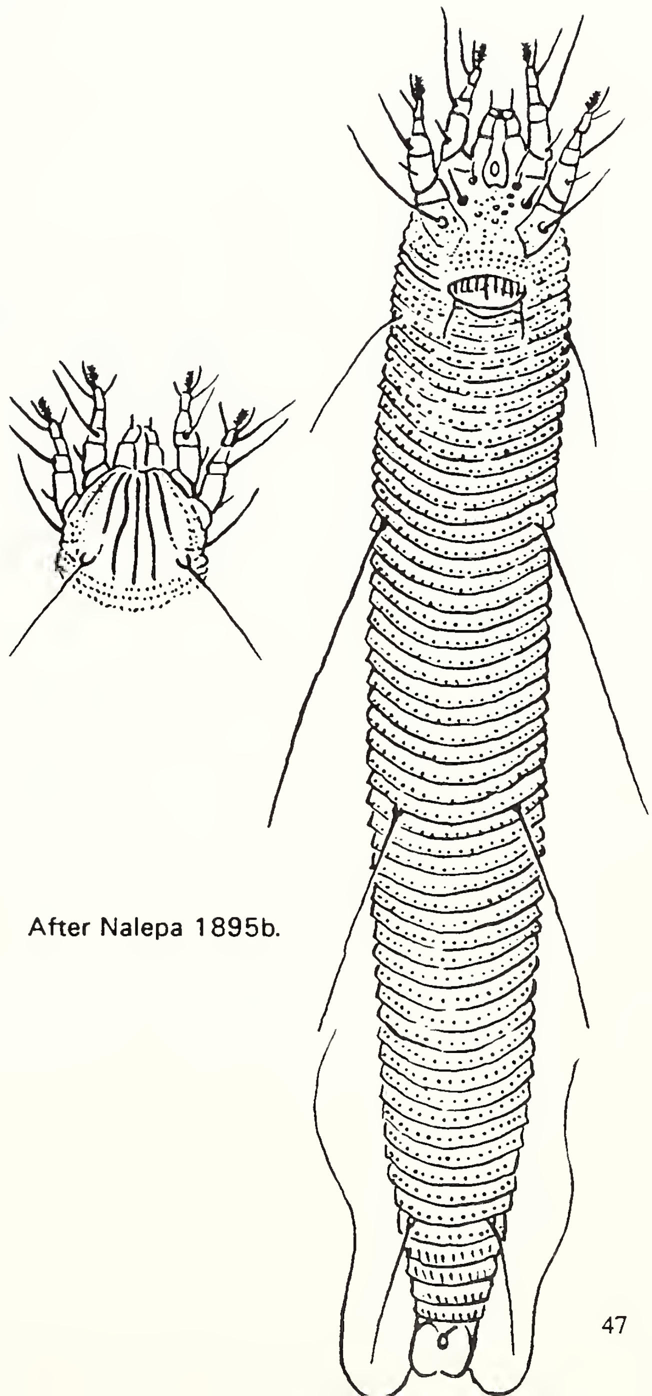
ex Keifer et al., 1982.

APPENDIX 3 (con't.)

Aceria scaber (Nalepa) 1893.
Synonymy: none.
Previous assignment: Phytoptus, Eriophyes, Aceria.
Host: Ribes alpinum (Grossulariaceae).
Host common name: Mountain Currant, Alpine Currant.
Alternate host(s): Ribes nigrum, R. rubrum.
Habit: flower and bud deformation.
Type locality: ?, Austria?(not stated).
Reference: Nalepa 1893e, Anzeiger 30(18):190; and 1895b, Denkschriften 62: 635, pl. 3, ff. 5,6; also Liro & Roivainen 1951, Äkämäpunkit, p. 51, f. 22 (foliar injury).

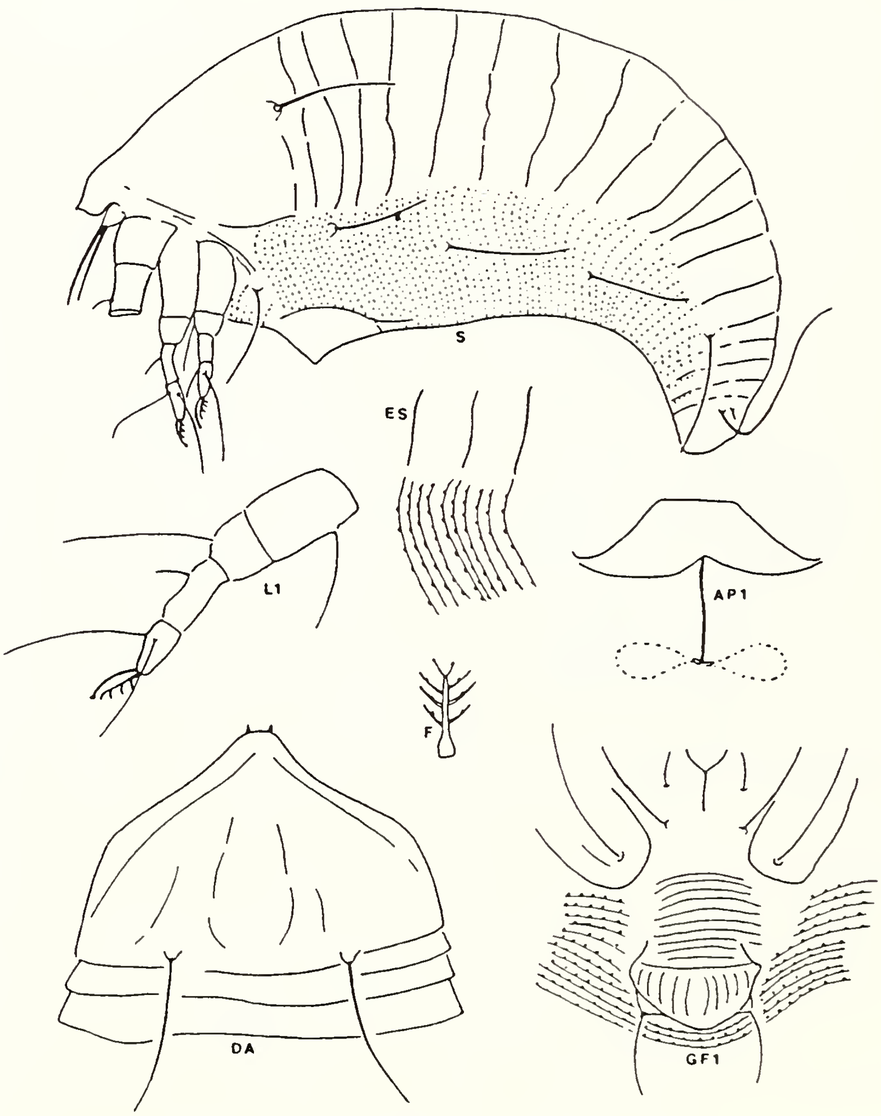


ex Liro & Roivainen 1951.



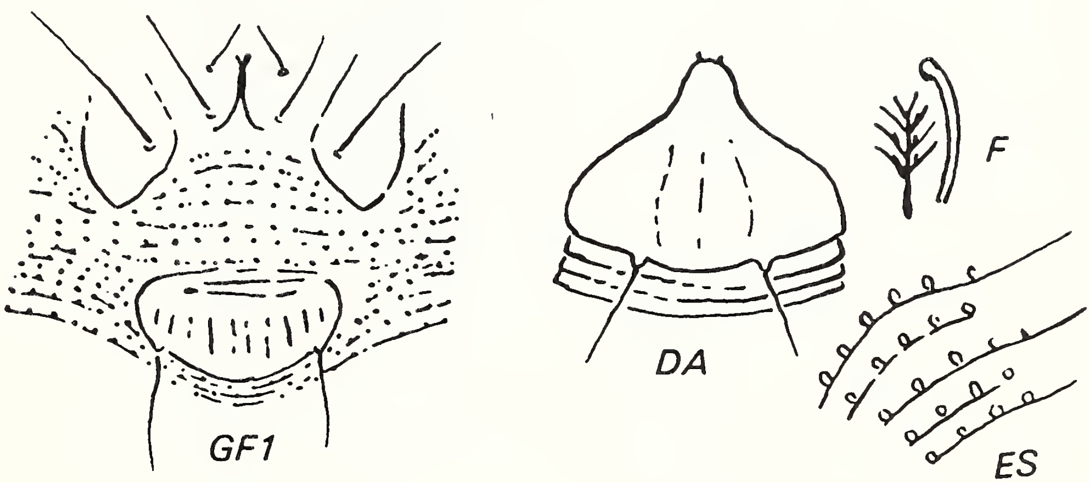
After Nalepa 1895b.

Aculus mansoni Amrine 1992.
Synonymy: new replacement name; Aculus ribis Manson 1989 is preoccupied by Aculus ribis (Massee) 1929.
Previous assignment: Aculus.
Host: Ribes nigrum (Grossulariaceae).
Host common name: Black Currant.
Alternate host(s): no.
Habit: undersurface leaf vagrant.
Type locality: Lincoln, Canterbury, New Zealand.
Reference: Manson 1989, New Zeal. J. Zool. 16(1): 44-45, f. 5.



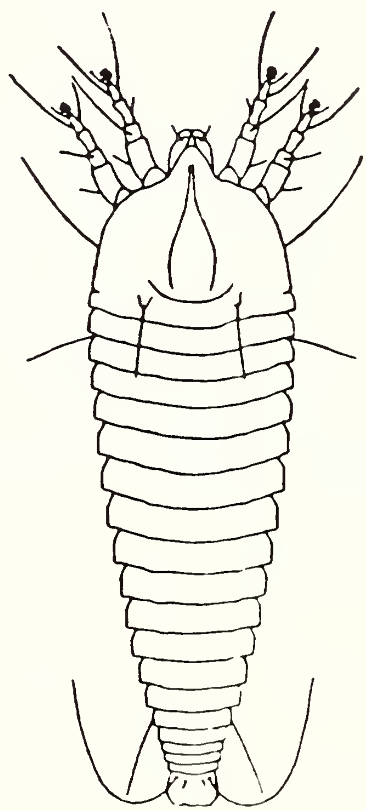
ex Manson 1989.

Aculus masseei (Nalepa) 1925.
Synonymy: none; new combination.
Previous assignment: Phyllocoptes, Vasates, Aculus.
Host: Ribes nigrum (Grossulariaceae).
Host common name: Black Currant.
Alternate host(s): Ribes alpinum, R. grossularia, R. rubrum.
Habit: vagrant.
Type locality: East Malling Research Station, Kent, England (col. by Massee), Great Britain.
Reference: Nalepa 1925b, Marcellia 21(1-6): 95-96 (no figure); also Boczek 1968, Bull. Acad. Polonaise Sci. Cl. V. 16(11): 684-685, pl. 3.



After Boczek 1968.

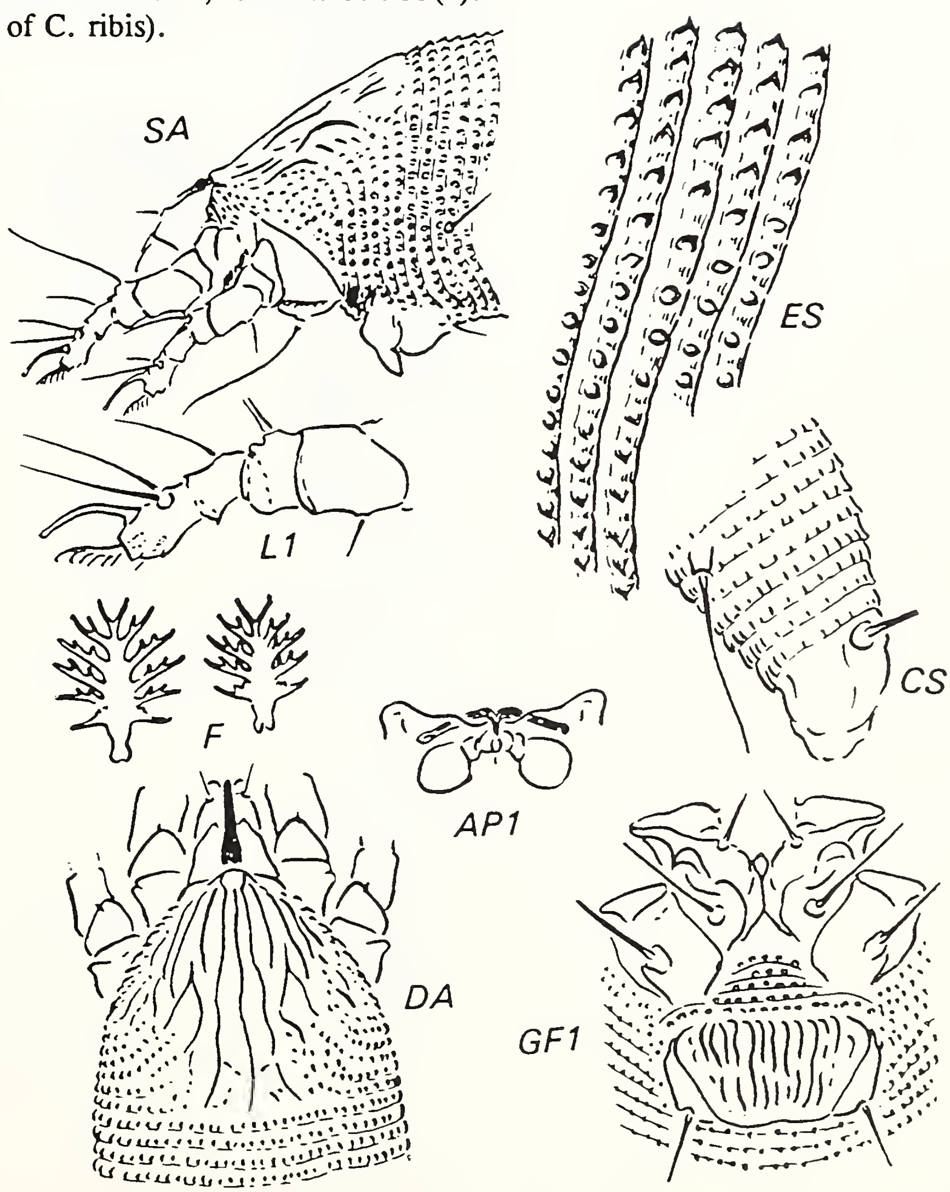
Aculus ribis (Massee) 1929.
Synonymy: none; new combination.
Previous assignment: Anthocoptes, Aculus.
Host: Ribes nigrum (Grossulariaceae).
Host common name: Black Currant.
Alternate host(s): Ribes alpinum, R. rubrum.
Habit: vagrant.
Type locality: Ontario, Canada.
Reference: Massee 1929, Ann. Mag. Nat. Hist. 10(3): 213-215 (no fig.); also, see Liro 1943, Ann. Zool. Soc. Zool.-Bot. Fenn., Venamo 9(3): 3, f. 2.



ex Liro 1943.

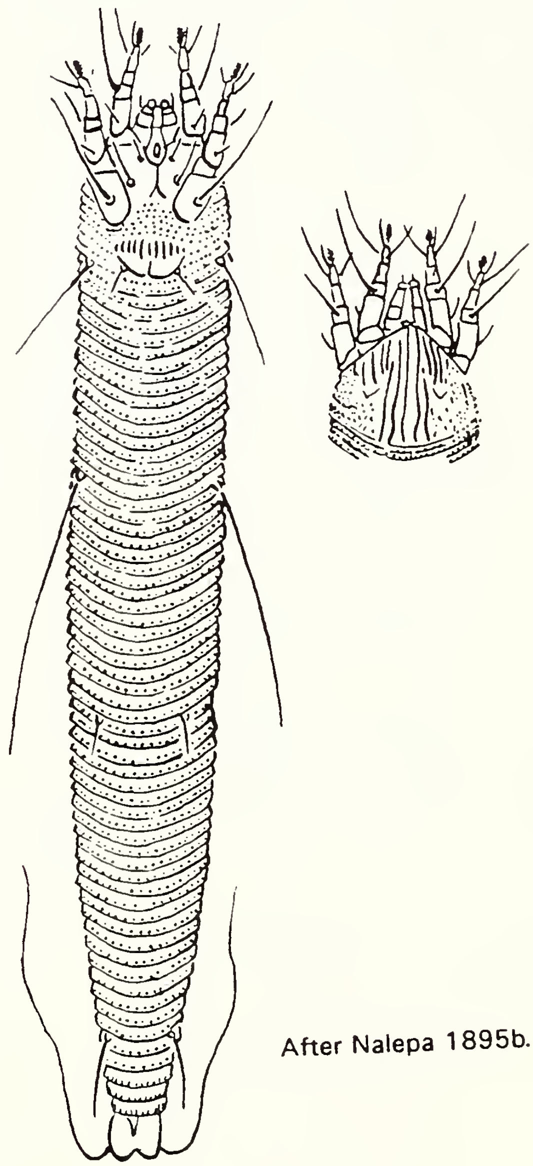
APPENDIX 3 (con't.)

Cecidophyopsis grossulariae (Collinge) 1907.
Synonymy: none.
Previous assignment: Eriophyes, Cecidophyopsis.
Host: Ribes grossularia (Grossulariaceae).
Host common name: English Gooseberry.
Alternate host(s): R. grossularia vars., R. curvatum, R. nigrum, R. rubrum
Habit: shriveled, dried buds (normal size); foliar deforma tion, cavities at base of veins on leaf blade undersurface, small bumps and callosities on leaf blades (both surfaces); the mites overwinter under bud scales, beginning in August.
Type locality: Easham, England.
Reference: Collinge 1907, Gardener's Chronicle p. 177; also, Keifer 1975, Injurious Eriophyoidea in Jeppson, Baker and Keifer, Mites Injurious to Economic Plants, f. 109, p. 412 (as C. ribis W.); Easterbrook 1980, J. Hort. Sci. 55(1): 1-6 (as foliar forms of C. ribis).



ex Keifer 1975

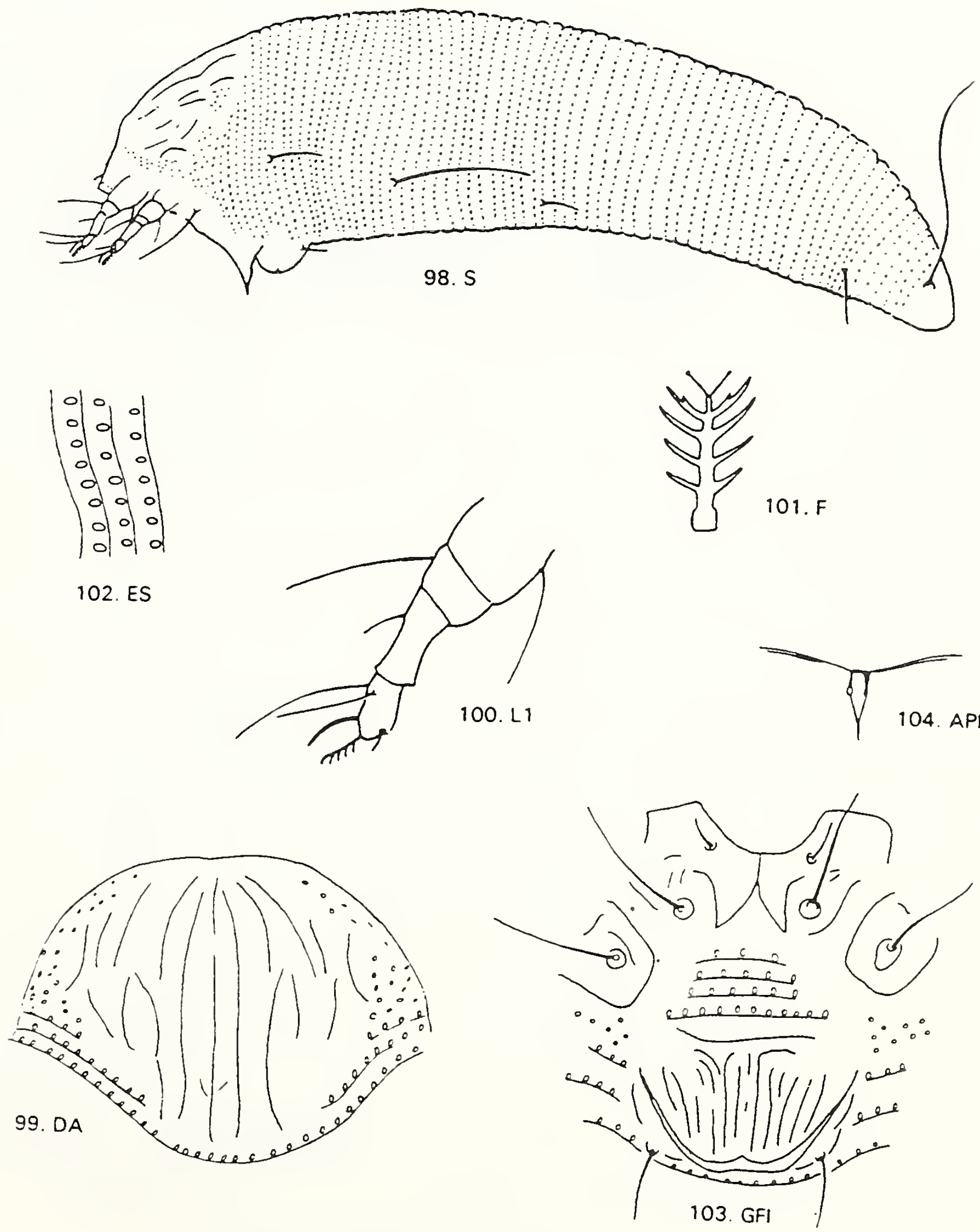
Cecidophyopsis ribis (Nalepa) 1893.
Synonymy: = Cecidophyopsis ribis (Westwood) 1869 (Nalepa 1929: 111).
Previous assignment: Phytoptus, Eriophyes, Cecidophyopsis.
Host: Ribes nigrum (Grossulariaceae).
Host common name: Black Currant.
Alternate host(s): no.
Habit: bud deformation.
Type locality: ?, Europe.
Reference: Nalepa 1893c, Anzeiger 30(12): 105; also, 1895b, Denkschriften 62: 634-635, pl. 3, ff. 3, 4.



After Nalepa 1895b.

APPENDIX 3 (con't.)

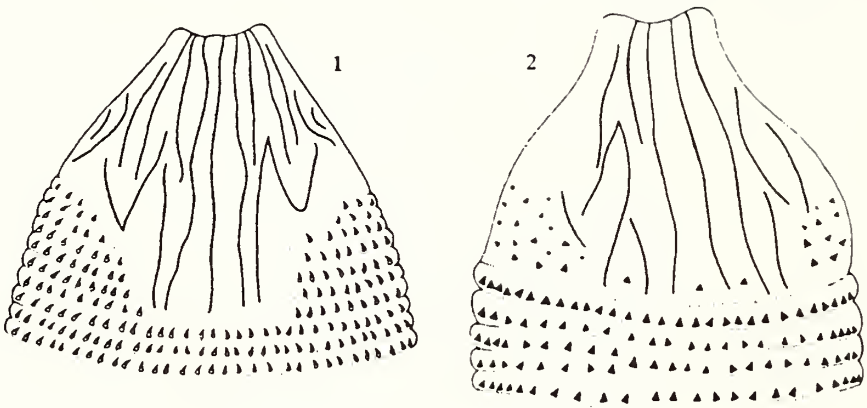
Cecidophyopsis ribis (Westwood) 1869.
Synonymy: none.
Previous assignment: Phytoptus, Eriophyes, Cecidophyes, Cecid ophyopsis.
Host: Ribes nigrum (Grossulariaceae).
Host common name: Black Currant.
Alternate host(s): Ribes alpinum (Roivainen 1951, p. 17).
Habit: bud galls, big buds; vector of Currant Reversion Disease to Black Currant.
Type locality: Blantyre (near Glasgow), Scotland, Great Britain.
Reference: Westwood 1869, Currant Bud Disease, p. 841 of Gardener's Chronical and Agric. Gazette; also, Manson 1984, Fauna N. Zeal. 4: 33-34, ff. 98-104.



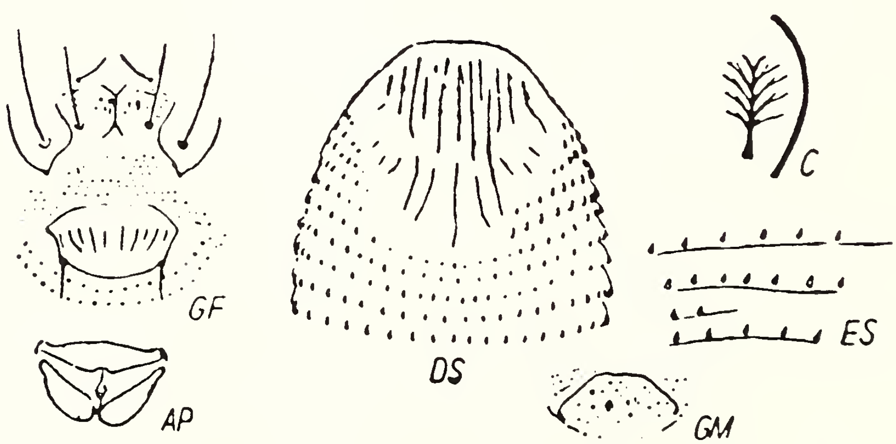
ex Manson 1984.

APPENDIX 3 (con't.)

Cecidophyopsis selachodon Eyndhoven 1967.
Synonymy: none.
Previous assignment: Cecidophyopsis.
Host: Ribes rubrum (Grossulariaceae).
Host common name: Red Currant.
Alternate host(s): no.
Habit: bud galls, big buds; vector (?) of Currant Reversion to Red Currant.
Type locality: Rijkstuinbouwconsulentschap, near Zutphen, The Netherlands.
Reference: Eyndhoven 1967, Entomol. Berichte (Amsterdam) 27: 149-151; also Boczek 1968, Bull. Acad. Polon. Sci. Cl. V. 16(10): 633, 635, pl. 6



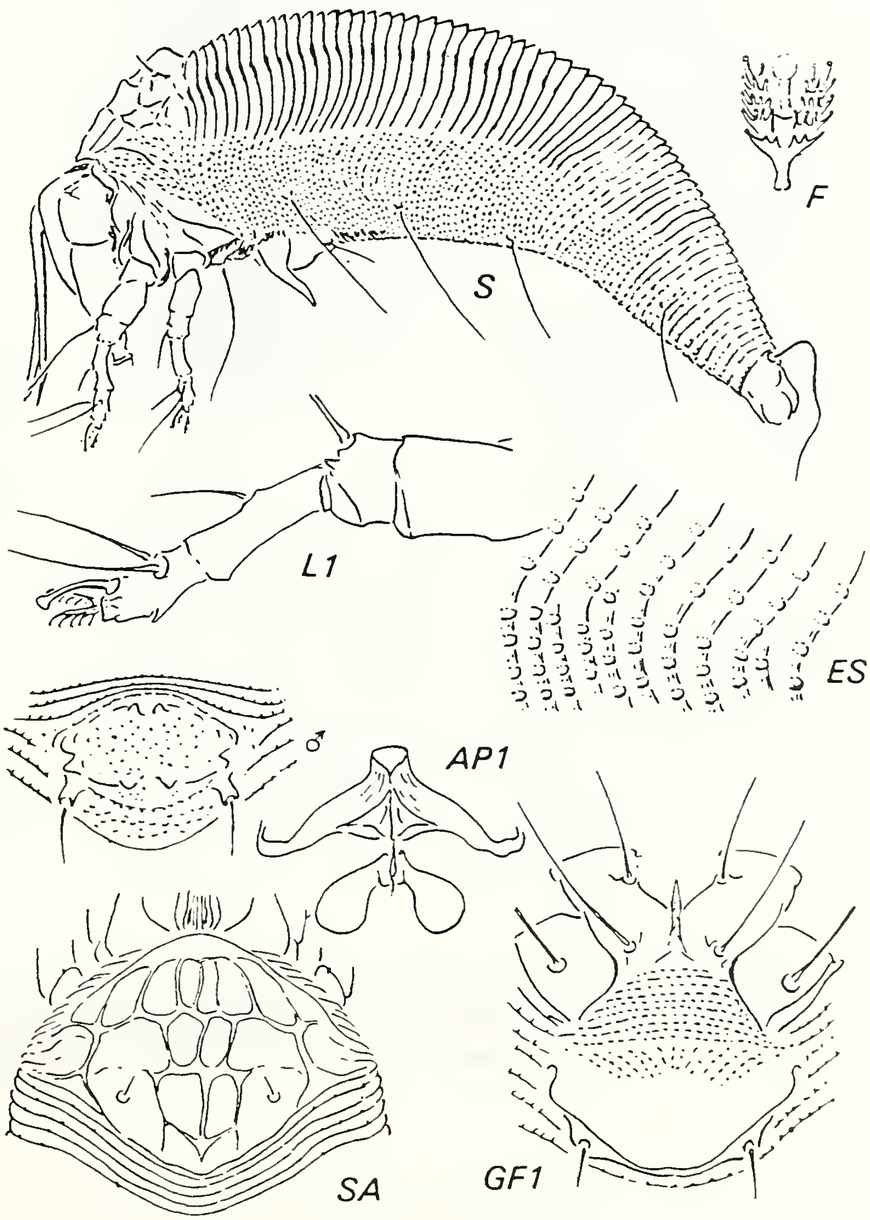
ex van Eyndhoven 1967: 1, *C. selachodon*; 2, *C. ribis*



ex Boczek 1968.

APPENDIX 3 (con't.)

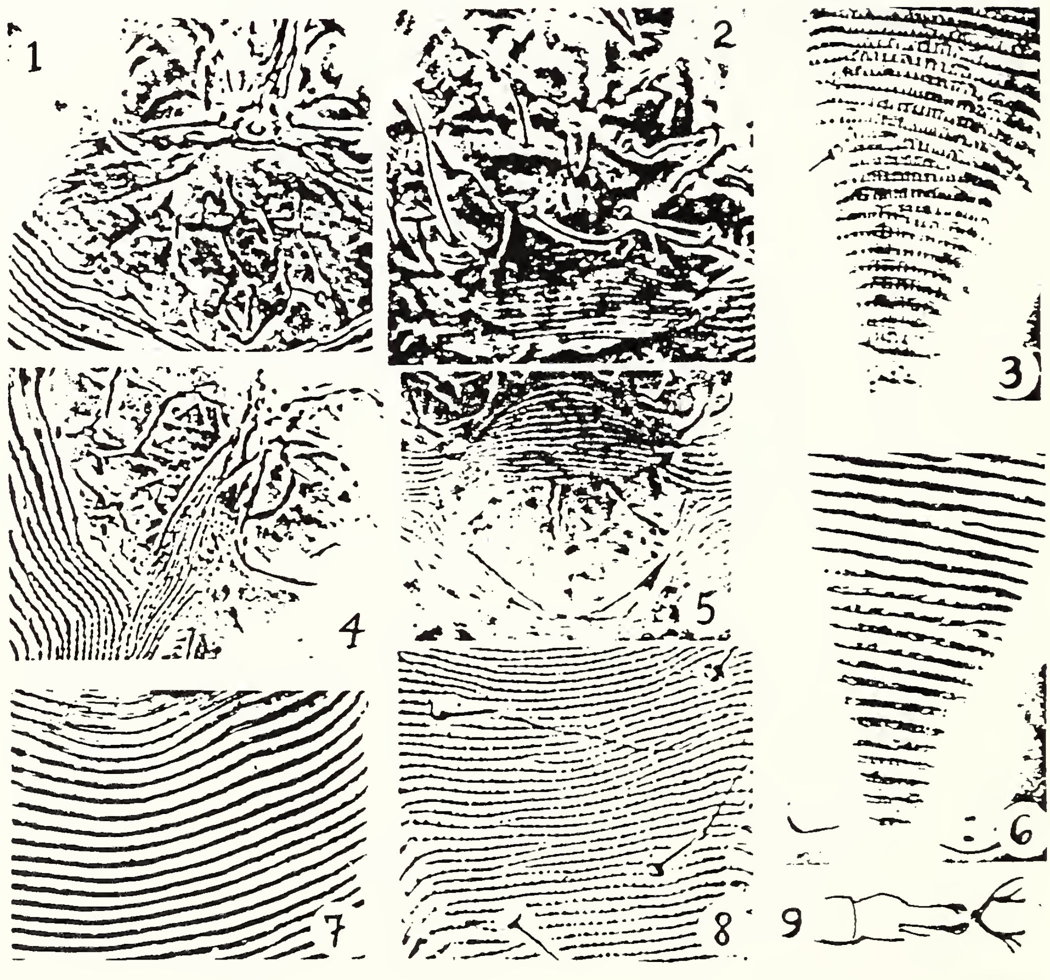
Diptacus gigantorhynchus (Nalepa) 1892.
Synonymy: none.
Previous assignment: Phyllocoptes, Epitrimerus, Diptilomiopus, Rhyncaphytoptus, Diptacus.
Host: Prunus domestica (Rosaceae).
Host common name: Domestic Plum.
Alternate host(s): Cydonia vulgaris, Grossularia sp., Prunus avium, P. cerasus, P. insititia, P. spinosa, Ribes rubrum.
Habit: vagrant, rust.
Type locality: ?, Austria?.
Reference: Nalepa 1892j, Anz. 29(19): 191; also, 1897b, Denks. 64: 392, pl. 4, f. 1, pl. 5., ff. 5, 6; Keifer 1975, Mites inj. to econom. plants: 525-526, f. 138; also, Manson 1984, Fauna New Zeal., No. 4, Eriophyoidea ex. Eriophy.: 28-29, 90-91, ff. 5



ex Keifer 1975.

APPENDIX 3 (con't.)

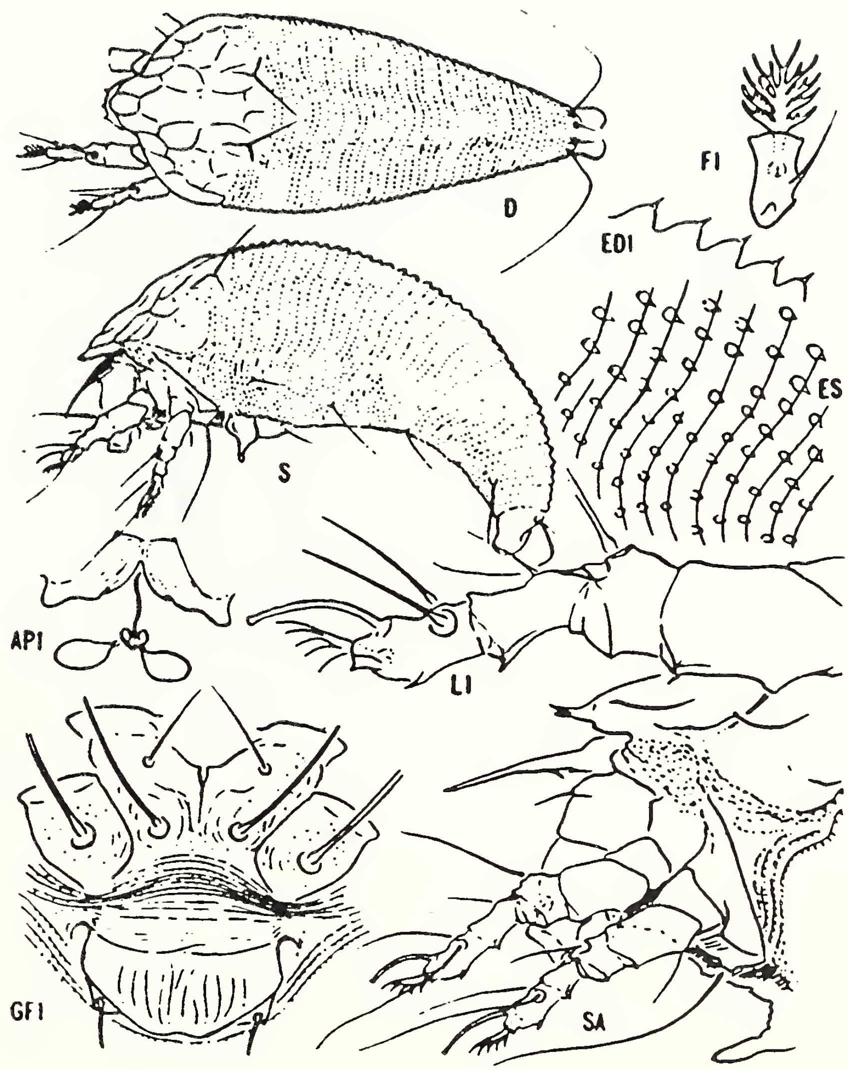
Diptacus pengsonae Briones & McDaniel 1976.
Synonymy: none.
Previous assignment: Diptacus.
Host: Ribes missouriense (Grossulariaceae).
Host common name: Missouri Gooseberry.
Alternate host(s): no.
Habit: distorted and crumpled leaves; undersurface vagrants.
Type locality: White, South Dakota.
Reference: Briones & McDaniel 1976, South Dakota St. Univ. Agric. Expt. Stn. Bull. 43: 62, pl. 39.



ex Briones and McDaniel 1976.
1 Dorsal shield; 2 Coxae, ventral surface; 3 Caudal hysterosoma, ventral; 4 Lateral margin of shield, left is dorsal; 5 Coxal-genital annuli and coverflap; 6 Caudal hysterosoma, dorsal; 7 Dorsal hysterosoma, posterior to shield; 8 Ventral hysterosoma, abdominal setae 1 & 2; 9 Tarsus of leg 1, divided empodium at right.

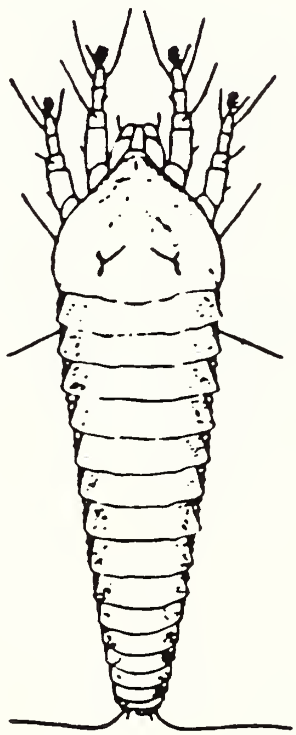
APPENDIX 3 (con't.)

Epitrimerus sierribis Keifer 1939.
Synonymy: none.
Previous assignment: Epitrimerus.
Host: Ribes nevadense (Grossulariaceae).
Host common name: Sierra Currant.
Alternate host(s): no.
Habit: vagrant.
Type locality: Baxters, Placer Co., California, USA.
Reference: Keifer 1939, E. S. 7, Bull. Cal. Dept. Agric. 28: 489-490, pl. 106.



ex Keifer 1939.

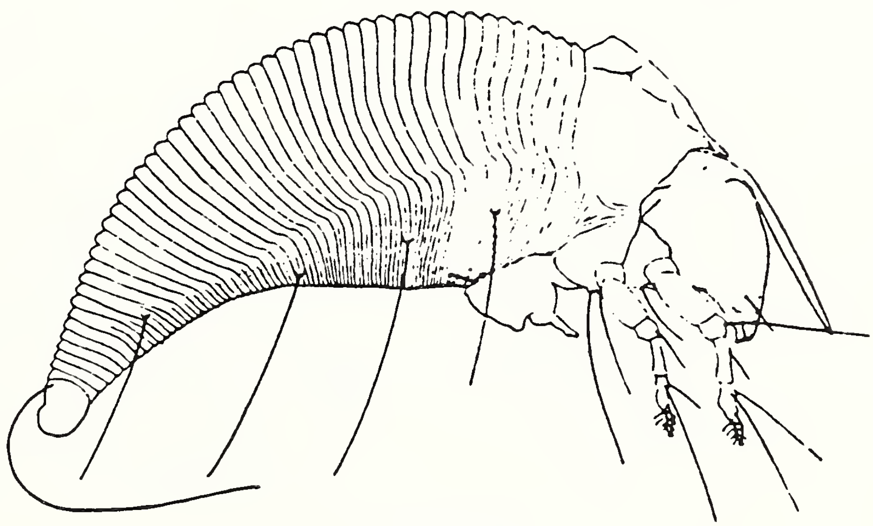
Phyllocoptes bellus (Liro) 1943.
Synonymy: none; new combination.
Previous assignment: Anthocoptes, Phyllocoptes.
Host: Ribes alpinum (Grossulariaceae).
Host common name: Mountain Currant.
Alternate host(s): no.
Habit: vagrant.
Type locality: Ostrobottnia australis, Kristiinankaupunki, Finland.
Reference: Liro 1943, Ann. Zool. Soc. Zool.-Bot. Fenn., Venamo 9(3): 2, f. 1.



ex Liro 1943.

APPENDIX 3 (con't.)

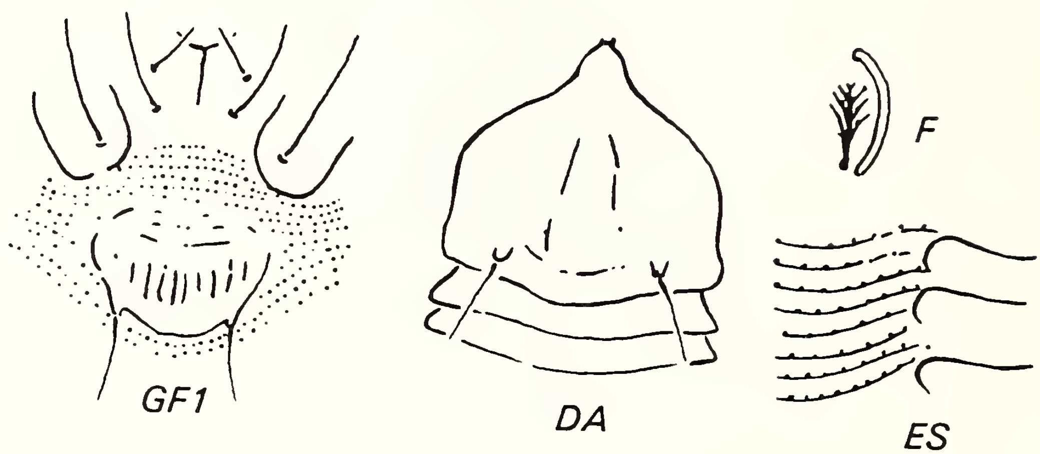
Rhyncaphytoptus tumidus Liro 1943.
Synonymy: none.
Previous assignment: Rhyncaphytoptus.
Host: Ribes alpinum (Grossulariaceae).
Host common name: Mountain Currant.
Alternate host(s): Ribes rubrum, R. grossularia
Habit: vagrant.
Type locality: Merimasku, Rantala, Regio turkuensis, Finland.
Reference: Liro 1943, Ann. Zool. Soc. Zool.-Bot. Fenn., Venamo 9(3): 43-45, f. 29.



ex Liro 1943.

APPENDIX 3 (con't.)

Shevtchenkella neglectus (Massee) 1927.
Synonymy: none.
Previous assignment: Oxypleurites, Tegonotus, Shevtchenkella.
Host: Ribes nigrum (Grossulariaceae).
Host common name: Black Currant.
Alternate host(s): no.
Habit: vagrant.
Type locality: East Malling Research Station, Maidstone, Kent, England, Great Britain.
Reference: Massee 1927, Bull. Entomol. Res. 18: 181, no fig ure; also, Boczek 1968, Bull. Acad. Polonaise Sci. Cl. V. 16(11): 683,685, pl. 1.



After Boczek 1968.

APPENDIX 3 (con't.)

Abreviations used in drawings:

AP, internal genital female apodeme.

AP1, internal genital apodeme and spermathecae of female.

C, "claw" (solenidion), and empodium.

CS, caudal section.

D, dorsal view.

DA, dorso-anterior view.

DS, dorsal shield.

ED1, detail of microtubercles, lateral view

ES, detail of side skin.

F, featherclaw or empodium.

GF, coxal-genital field.

GF1, coxae and genital structures of female.

GM, male genitalia.

L1, leg 1.

S, side view.

SA, side view, anterior.

APPENDIX 4: ***Ribes (Grossulariaceae)*: Host Index of Eriophyoidea.**
Prepared by: Dr. Jim Amrine

Ribes alpinum, Mountain Currant, Alpine Currant (Europe).

Aceria scaber (Nalepa) 1893.

Aculus masseei (Nalepa) 1925.

Phyllocoptes bellus (Liro) 1943.

Cecidophyopsis ribis (Westwood) 1869.

Rhyncaphytoptus tumidus Liro 1943.

Ribes curvatum, Unk. Colloquial Name (S. Central U. S.)

Cecidophyopsis grossulariae (Collinge) 1907

Ribes divaricatum, Coastal Black Gooseberry (Western U.S.)

Aceria breakeyi Keifer 1959.

Ribes grossularia, English Gooseberry (Europe).

Aculus masseei (Nalepa) 1925.

Cecidophyopsis grossulariae (Collinge) 1907.

Rhyncaphytoptus tumidus Liro 1943.

Ribes missouriensis, Missouri Gooseberry (Central U. S.).

Diptacus pengsonae Briones & McDaniel 1976.

Ribes nevadense, Sierra Currant (Western U.S.).

Epitrimerus sierribis Keifer 1939.

APPENDIX 4 (con't.)

Ribes nigrum, Black Currant (Europe).

Aceria scaber (Nalepa) 1893.

Aculus mansoni Amrine 1992.

Aculus masseei (Nalepa) 1925.

Aculus ribis Massee 1929.

Cecidophyopsis grossulariae (Collinge) 1907

Cecidophyopsis ribis (Westwood) 1869.

Shevtchenkella neglectus (Massee) 1927.

Ribes roezlii, Sierra Gooseberry (Western U. S.).

Aceria breakeyi Keifer 1959.

Ribes rubrum, Red Currant (Europe).

Aceria scaber (Nalepa) 1893.

Cecidophyopsis grossulariae (Collinge) 1907

Cecidophyopsis selachodon Eyndhoven 1967.

Diptacus gigantorhynchus (Nalepa) 1892.

Rhyncaphytoptus tumidus Liro 1943.

Shevtchenkella neglectus (Massee) 1927.

Ribes sanguineum, Red Flowering Currant (Western U. S).

Cecidophyopsis ribis (Westwood) 1869.

APPENDIX 5: **Taxonomic References to Eriophyid Mites Attacking Ribes spp.**
Prepared by: Dr. Jim Amrine

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Prepared by: Dr. Jim Amrine
5 October 1992

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